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USER'S MANUAL FOR COPTRAN, A METHOD OF OPTIMUM COMMUNICATION SYSTEM DESIGN

By L. S. Stokes, K. L. Brinkman
and
W. K. Pratt

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REVISION 1

ELECTRONICS RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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CONTENTS

USER'S MANUAL FOR COPTRAN,
A METHOD OF OPTIMUM COMMUNICATION SYSTEM DESIGN

The COPTRAN user's manual constitutes Section 4.0 of the final report for Contract NAS 12-566. This section is designed to be self-contained relative to the explanation of COPTRAN usage. However the remainder of the Final Report and the Phase I and Phase II Interim Reports for NAS 12-566 should be consulted for greater context into which COPTRAN programming fits.

4.0 USER'S MANUAL FOR COPTRAN, A METHOD OF OPTIMUM COMMUNICATION SYSTEM DESIGN

4.1 Introduction

Calculations to determine communication capability of a transmission link are basically dependent on a single equation, the one way transmission equation. While there are variants in this equation to account for different types of noise, modulation and demodulation techniques, this one equation documents the interrelationships among the communication parameters of range, transmitter power, antenna gains, noise, etc. Since these parameters are multiplicative in the range equation it is possible to trade one parameter value against others while maintaining a given performance. Thus, it is difficult in many cases, to determine the "best" combination of parameters for a particular application although this is an important determination, especially to space missions.

It is therefore desirable to formulate an analytical method or methodology of not only selecting parameters which produce the desired performance within the regulation of the range equation but of selecting <u>optimum</u> parameter values which meet the desired performance.

Consider the following relatively simple optimization example for a deep space communication system. The effective radiated power from a spacecraft is to be maximized for a specified maximum weight. Now the effective radiated power may be increased by increasing either the size of the transmitting antenna or the transmitter power, or by some suitable combination of increases in these two parameters. The problem is to determine the proper split in weight between these two elements to maximize the effective radiated power subject to the given weight constraint. Clearly, the combination of an extremely large antenna using almost all the available weight with a minimal transmitter would not give the best possible performance, nor would the combination of an extremely heavy transmitter with a very low-gain antenna. The optimum configuration must therefore lie somewhere between these two extremes. In order to determine the optimum configuration, both transmitter power and antenna gain must be expressed in terms of weight. If these two relationships are known, a straight forward optimization

procedure can be employed to determine the optimum values for both transmitter power and the antenna size associated with the resulting antenna gain.

Such a concept has been expanded to all applicable parameter values in the range equation for both a weight optimization and a cost optimization. The resulting methodology has been implemented in a computer program known as COPS (Communication system Optimization Program with Stops).

The COPS program optimizes the values of the Major Communication Systems Parameters which are: the transmitter antenna diameter or gain, the receiver antenna diameter or gain, the transmitter power, and the receiver field of view. The program is implemented for radio frequency homodyne detection systems, optical frequency heterodyne detection systems, and for optical frequency thermal or shot noise limited direct detection systems.

The COPS program maximizes the signal-to-noise ratio, the transmission range, and the information rate and minimizes the probability of detection error for each communication system. The optimization uses as a criteria, the transmitter system weight, transmitter system fabrication cost, receiver system weight, receiver system fabrication cost either singly or in any combination. Fixed values for any of the Major System Parameters may be entered into the programs. In addition, maximum parameter values or "stops" may be placed on each of the Major System Parameters.

The COPS program provides a tabulation of optimum values of Major System Parameters as a function of information rate as outputs. Other outputs include: optimum transmitter antenna diameter or gain versus information rate; optimum receiver antenna diameter or gain versus information rate; optimum transmitter power versus information rate; and optimum receiver field of view versus information rate.

The inputs required for the COPS program are a tabulation of Systems Physical Data such as: range, sky noise background, wavelength, transmissivity losses etc; System Burdens Data such as: constants relating transmitter power to weight; antenna size to cost; etc., and System Parameter Constraints such as the maximum or fixed values for the Major Systems Parameters.

The COPS program has been written in Fortran IV language. In order to facilitate the use of the COPS program by persons unfamiliar with computer operation or programming, a buffer computer language called COPTRAN (Communication system Optimization Program TRANslator) has been developed.

To operate the COPS optimization program using the COPTRAN language involves answering a few simple questions which are written in the language of the user. For instance one question is: "What is the transmission range?" Following this question is a choice of four six letter mnemonics and their meanings. One of these, RANMAR, may be chosen to tell the COPS methodology through the COPTRAN buffer language that the range (RAN) is a Mars (MAR) distance, 10^8 km.

Similar simple questions, again using a multiple choice listing of mnemonics, are answered for such topics as the modulation type, the type of optimization desired, the type of output desired, etc.

The user may also use standard sets of data for the interrelationship of transmitter cost to power, etc. (burden relationships). Or if the user desires, he may change one or all the nominal constants, thus superceding the stored values.

The mnemonic answers and data values that are selected by the user to describe the problem he wishes to solve are written down by the user on a simple COPTRAN form. This form is then used to punch computer cards, one card per mnemonic or data value. The cards become part of the COPTRAN program and are batch processed by a computer.

The computer results are returned to the user either in a line printout or in Cal Comp plots.

Figure 4-1 summarizes the steps in obtaining optimized communications parameters using the COPS computer program with the COPTRAN language.

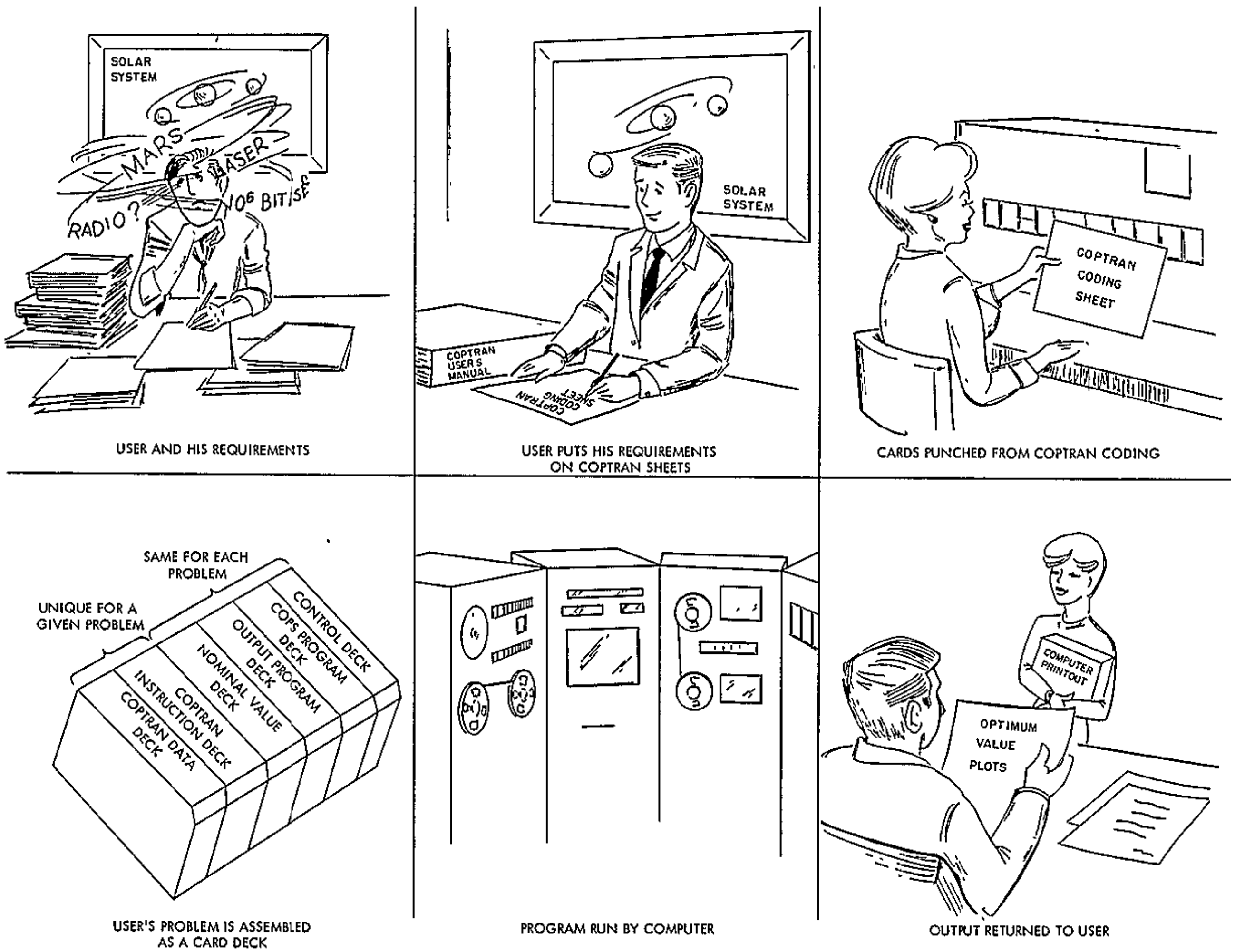

Figure 4-1. COPTRAN Programming

4.2 COPTRAN Programming Structure

4.2.1 Introduction. – COPTRAN programming language is a specialized, simple computer language used in the design of communication systems. COPTRAN allows a user to determine the optimum configuration of a communication system with relatively few instructions phrased in the context of his problem and without the necessity of supplying large quantities of data to the computer. This is accomplished by storing nominal values of the program data in the computer data banks. The pertinent data for a particular problem is then automatically fetched by the COPTRAN program unless countermanded by particular user selections.

The COPTRAN program structure is composed of six main parts. These parts are: 1) The Control Program Deck, 2) the COPS Program Deck, 3) the Output Program Deck, 4) the Nominal Value Decks, 5) The COPTRAN Instruction Deck, and 6) the COPTRAN Data Deck. Of these, only the last two are of concern to the COPTRAN user, and in many cases, only the COPTRAN Instruction Deck will be needed. It is the purpose of this instruction manual to describe these two portions of the COPTRAN Program in detail.

4.2.2 COPTRAN instruction deck. – The COPTRAN Instruction Deck is composed of punched cards, each of which has a single mnemonic. The mnemonics describe the communications problem to be solved in the following five categories.

1. Physical Environment
   - Transmitter location (spacecraft)
   - Receiver location (earth)
   - Transmission range (one of a set of selected ranges may be chosen to indicate physical environment or another range choice may be made and the environment specified)
   - Background (choice of physical source of background radiation)

2. Communication System
   - Transmission wavelength (one selected wavelength may be chosen)

Modulation and demodulation methods (choice of one of several sets are available)

3. Optimization

Optimization basis (transmitter system weight, transmitter system fabrication cost, receiver system weight, and receiver system fabrication cost may be minimized individually or in any combination)

Antenna parameter optimization (transmitter antenna gain or diameter and receiver antenna gain or diameter may be optimized)

4. Nominal System Burdens* (see Section 4.5 for data description)

Choices of system burdens may be made from a data bank list if automatic selections are not desired. (Section 4.6 describes automatic data selection.) System burdens values may also be entered as new data if desired.

5. Processing

Computation format (choice of initial and final values of information rate and number of information rate data points calculated)

Print format (choice of data and results to be printed in tabular form)

Plot format (choice of results to be plotted by Cal Comp plotter)

4.2.3 COPTRAN data deck. – The COPTRAN Data Deck is the means by which individual burdens, physical data, stops, and fixed values are inserted into the COPTRAN program. If the automatic burdens and physical data

*Burdens are the "constants" which represent the modeled relationship between system parameters such as transmitter power, P_T, and weight of the transmitter, W_{P_T}. In the following equation W_{KP}, K_{W_T}, and h_T are "burdens": $W_{P_T} = W_{KP} + K_{W_T}(P_T)^{h_T}$.

selections provided by the COPTRAN instructions are acceptable to the user, and no parameter stops or fixed values are specified, there will be no COPTRAN Data Deck for the COPTRAN program (except an end data card, ENDDAT). The COPTRAN program has been developed so that input data in the COPTRAN Data Deck automatically replaces items of data normally selected from data banks. The program data is of three types.

1. <u>System Physical Data</u>

   Physical data such as signal-to-noise rate, atmospheric transmissivity, receiver temperature, etc.

2. <u>System Burdens Data</u>

   Weight, fabrication cost, and power requirement burdens for communication system components.

3. <u>System Parameter Constraints</u>

   Fixed and stop values of the Major Communication System Parameters namely transmitting or receiving antenna gains or diameters, transmitter power, and receiver field of view. (A"fixed" parameter value is one that remains fixed throughout all portions of the optimization. A "stop" in the parameter value is the maximum value the parameter may take. For instance, a communication problem may require a fixed antenna diameter for a receiving antenna on earth of 64 meters and have a stop value for a space antenna diameter of 10 meters. The optimization program will determine the optimum split between the spacecraft antenna size as a function of data rate. As the data rate requirements increase, the transmitter power and antenna size will increase until the antenna size of 10 meters is reached. For larger data rates, the antenna size will remain at 10 meters and the transmitter power will increase, at a faster rate now, to meet the demands of higher data rates.)

MISSING PAGE

4.3 COPTRAN Use

A COPTRAN program is considered to be the set of COPTRAN instructions and COPTRAN data cards which describe the communication system(s) to be optimized. This program, when submitted with the proper control cards and the COPTRAN card decks comprises a COPTRAN job. The COPTRAN card decks are supplied to the user and may not be altered. A typical COPTRAN job deck structure is shown in Figure 4-2. The COPTRAN instruction and data cards which must be supplied by the user are described in the following paragraphs.

The job deck set-up shown in Figure 4-2 is for a particular computer system: The GE 635 GECOS III system. No matter what physical system is used, the COPTRAN card decks and the COPTRAN program will be the same. The control cards, however, (identified by a '$' in card column 1) will vary with the system. They are pictured here to indicate relative location in a job deck and the information required. The operations staff of a particular facility should be contacted for more specific information on control cards.

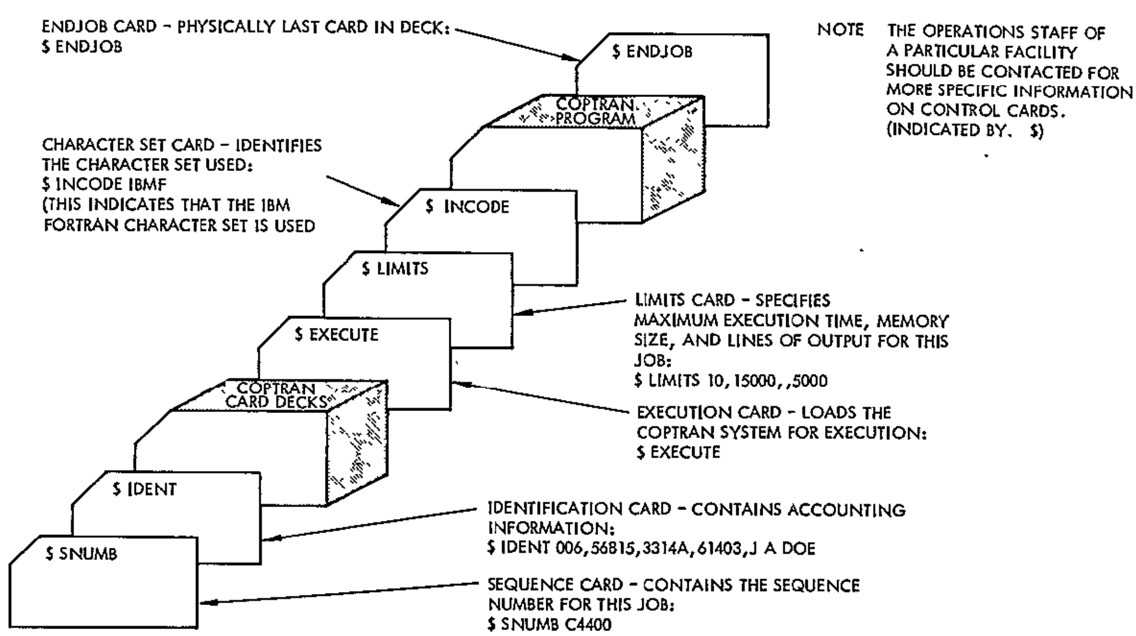

Figure 4-2. COPTRAN Job Deck Structure

4.3.1 COPTRAN program description. — A COPTRAN program is composed of single COPTRAN mnemonic instructions and a set of data values supplied to the program, where they are different from the ones automatically supplied by the COPTRAN system. Each instruction is entered in columns 1-6 of one line of the COPTRAN coding sheet (see Figure 4-3). In order to properly specify a problem, the user should consider the instruction choices from each of the categories in Table IV-I. In some cases, more than one instruction in one category may be supplied. The remarks in each category in Table IV-I indicate the options which are available. It is suggested that the user prepare his program by examining each category in Table IV-I in sequence and selecting the instruction(s) from that category which best describe(s) his problem. It is important to note the restrictions which are placed on the use of certain instructions.

COPTRAN CODING SHEET A

NAME ____________________ DATE __________ PROBLEM ____________________

COPTRAN INSTRUCTIONS AND DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
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Figure 4-3. COPTRAN Coding Sheet A

TABLE IV-I
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

1. Transmitter Location (Only one available)

SPXMTR	Spacecraft transmitter

2. Receiver Location (Only one available)

EARCVR	Earth receiver

3. Transmission Range (Choose only one)

RANMAR	Mars range (10^{13} cm)
RANJUP	Jupiter range (7.5×10^{13} cm)
RANSAT	Synchronous satellite range (3.6×10^{9} cm)
RANOTH	Range other than those above will be supplied with COPTRAN data. In addition, power supply burdens affected by range must be supplied by the user and included with COPTRAN data.

4. Transmission Wavelength (Choose only one)

LAM051	$\lambda = 0.51$ micron
LAM084	$\lambda = 0.84$ micron
LAM106	$\lambda = 10.6$ microns
LAM13C	$\lambda = 13$ cm (2.3 GHz)

5. Background (Choose only one)

BKDSKY	Day sky (for optical transmission)
BKNSKY	Night sky (for optical transmission)
BKGALT	Galactic (for radio transmission)

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

6. Modulation and Demodulation Methods (Choose only one modulation and demodulation method pair)

PCM/AM	PCM amplitude modulation
OPTDIR	Optical direct detection (Use only when λ = 10.6 microns. No other burdens are available.)
PCM/PL	PCM polarization modulation
OPTDIR	Optical direct detection (Use only when λ = 0.51 microns. No other burdens are available.)
PCM/FM	PCM frequency modulation
OPTHET	Optical heterodyne detection (Use only when λ = 10.6 microns. No other burdens are available.)
PCM/PM	PCM phase modulation
RADHOM	Radio homodyne detection (Use only when λ = 13 cm. No other burdens are available.)
PCM/PS	PCM pulse shift modulation
OPTDIR	Optical direct detection (Use only when λ = 0.51 microns. No other burdens are available.)

7. Optimization Basis (Choose at least one)

[Note: If receiver parameters d_R and θ_R or transmitter parameters d_T and P_T are not to be optimized in weight or fabrication cost, their fixed values must be given in the COPTRAN data deck. Selection of more than one instruction in this category provides joint optimization of burdens (i.e., fabrication cost or weight) selected.]

XMWTOP	Transmitter weight optimization
RCWTOP	Receiver weight optimization
XMFCOP	Transmitter fabrication cost optimization
RCFCOP	Receiver fabrication cost optimization

8. Antenna Parameter Optimization (Choose only one)

DTDROP	Transmitter antenna diameter and receiver antenna diameter optimization
GTDROP	Transmitter antenna gain and receiver antenna diameter optimization. (Use only with radio systems

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

DTGROP	Transmitter antenna diameter and receiver antenna gain optimization. (Use only with radio systems)
GTGROP	Transmitter antenna gain and receiver antenna gain optimization. (Use only with radio systems)

9. Nominal System Burdens Data (Choose one from each set desired. See section 4.5 for detail value listing.)

(Note: If no choice is made, program automatically selects burdens based on internal logic. See section 4.6.)

Transmitter Antenna Burdens

NXANTA	λ = 0.51 microns, spacecraft
NXANTC	λ = 0.84 microns, spacecraft
NXANTD	λ = 10.6 microns, spacecraft
NXANTF	λ = 13 cm, diameter burdens, spacecraft
NXANTG	λ = 13 cm, gain burdens, spacecraft

Receiver Antenna Burdens

NRANTA	λ = 0.51 microns, optical direct detection, earth
NRANTB	λ = 0.51 microns, optical heterodyne or homodyne detection, earth
NRANTC	λ = 0.84 microns, optical direct detection, earth
NRANTD	λ = 10.6 microns, optical direct detection, earth
NRANTE	λ = 10.6 microns, optical heterodyne or homodyne detection, earth
NRANTF	λ = 13 cm, diameter burdens, earth
NRANTG	λ = 13 cm, gain burdens, earth

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

Transmitter Acquisition and Track Burdens	
NXACTA	Optical frequencies, spacecraft
NXACTB	Radio frequencies, spacecraft, diameter burdens
NXACTC	Radio frequencies, spacecraft, gain burdens
Receiver Acquisition and Track Burdens	
NRACTA	Optical frequencies, earth
NRACTB	Radio frequencies, earth, diameter burdens
NRACTC	Radio frequencies, earth, gain burdens
Modulation Equipment Burdens	
NMODEA	λ = 0.51 microns, CW laser, spacecraft
NMODEB	λ = 0.84 microns, CW laser, spacecraft
NMODEC	λ = 0.84 microns, pulsed laser, spacecraft
NMODED	λ = 10.6 microns, CW laser, spacecraft
NMODEE	λ = 13 cm, spacecraft
NMODEF	λ = 0.51 microns, CW laser, earth
NMODEG	λ = 0.84 microns, CW laser, earth
NMODEH	λ = 0.84 microns, pulsed laser, earth
NMODEI	λ = 10.6 microns, CW laser, earth
NMODEJ	λ = 13 cm, earth
Demodulation Equipment Burdens	
NDMODA	Optical direct detection, earth
NDMODB	Optical heterodyne detection, earth
NDMODC	Optical homodyne detection, earth
NDMODE	13 cm radio homodyne detection, earth
NDMODF	Optical direct detection, spacecraft
NDMODG	Optical heterodyne detection, spacecraft
NDMODH	Optical homodyne detection, spacecraft
NDMODI	13 cm radio direct detection, spacecraft
NDMODJ	13 cm radio homodyne detection, spacecraft

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

	Transmitter Power Supply Burdens
NXPWSA	RTG, spacecraft
NXPWSB	Reactor, spacecraft
NXPWSC	Solar cell, Mars, Spacecraft
NXPWSD	Generator, earth
NXPWSE	Solar cell, satellite, spacecraft
NXPWSF	Solar cell, Venus, spacecraft
NXPWSG	Solar cell, Mercury, spacecraft
	Receiver Power Supply Burdens
NRPWSA	RTG, spacecraft
NRPWSB	Reactor, spacecraft
NRPWSC	Solar cell, Mars, spacecraft
NRPWSD	Generator, earth
NRPWSE	Solar cell, satellite, spacecraft
NRPWSF	Solar cell, Venus, spacecraft
NRPWSG	Solar cell, Mercury, spacecraft
	Transmitter Burdens
NXMTRA	λ = 0.51 microns, spacecraft
NXMTRB	λ = 0.51 microns, earth
NXMTRE	λ = 10.6 microns, spacecraft
NXMTRF	λ = 10.6 microns, earth
NXMTRG	λ = 13 cm, spacecraft
NXMTRH	λ = 13 cm, earth

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

10. Computation Format — Choose one of each

RBFRQ___ — Number of information rate computations per decade, 1, 2, 4, 5, 8, 0 according to following table

RBFRQ1	RBFRQ2	RBFRQ4	RBFRQ5	RBFRQ8	RBFRQ0
10^n	10^n	10^n	10^n	10^n	10^n
10^{n-1}	0.5×10^n	0.75×10^n	0.8×10^n	0.875×10^n	0.9×10^n
	10^{n-1}	0.50×10^n	0.6×10^n	0.750×10^n	0.8×10^n
		0.25×10^n	0.4×10^n	0.625×10^n	0.7×10^n
		10^{n-1}	0.2×10^n	0.500×10^n	0.6×10^n
			10^{n-1}	0.375×10^n	0.5×10^n
				0.250×10^n	0.4×10^n
				0.125×10^n	0.3×10^n
				10^{n-1}	0.2×10^n
					10^{n-1}

RBINT___ — Initial information rate, exponent 0 to 8 (e.g., $R_B = 10^0, 10^1, \ldots, 10^8$)

RBFIN___ — Final information rate, exponent 1 to 9 (e.g., $R_B = 10^1, 10^2, \ldots, 10^9$)
Note that final information rate must be greater than initial information rate

11. Print Format — Choose sets desired

PRTBUR — Print system burdens data

PRTSPD — Print system physical data

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

	PRTSNC	Print signal-to-noise ratio constants
	PRTBRC	Print system burden constants
	PRTSPC	Print parameter constraints
	PRTOPT	Print optimum system parameters
	PRTWGT	Print weight burdens for optimum system parameters
	PRTPWP	Print power burdens for optimum system parameters
	PRTFAB	Print fabrication cost burdens for optimum system parameters
	PRTSYC	Print system cost burdens for optimum system parameters
	PRTALL	Prints all of above data
	PRTDAT	Print system burdens data, systems physical data, signal-to-noise ratio constants, system burden constants, and system parameter constants.
	PRTWTH	Print WORTH. (See section 4. 3. 2.)
12.	<u>Plot Format</u>	Choose up to five as desired
	PLTOPT	Plot optimum system parameters
	PLTDTO	Plot optimum value of transmitter antenna diameter
	PLTGTO	Plot optimum value of transmitter antenna gain
	PLTDRO	Plot optimum value of receiver antenna diameter
	PLTGRO	Plot optimum value of receiver antenna gain
	PLTPTO	Plot optimum value of transmitter power
	PLTTRO	Plot optimum value of receiver field of view
	PLTWDT	Plot transmitter antenna weight
	PLTWDR	Plot receiver antenna weight
	PLTWQT	Plot transmitter acquisition and track equipment weight
	PLTWQR	Plot receiver acquisition and track equipment weight
	PLTWX	Plot transmitter weight

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

PLTWH	Plot transmitter heat exchanger weight
PLTWM	Plot modulation equipment weight
PLTWD	Plot demodulation equipment weight
PLTWST	Plot transmitter power supply weight
PLTWSR	Plot receiver power supply weight
PLTWA	Plot transmitter system weight
PLTWB	Plot receiver system weight
PLTPQT	Plot transmitter acquisition and track equipment power requirement
PLTPQR	Plot receiver acquisition and track equipment power requirement
PLTPX	Plot transmitter power requirement
PLTPM	Plot modulation equipment power requirement
PLTPD	Plot demodulation equipment power requirement
PLTPA	Plot transmitter system power requirement
PLTPB	Plot receiver system power requirement
PLTCDT	Plot transmitter antenna fabrication cost
PLTCDR	Plot receiver antenna fabrication cost
PLTCQT	Plot transmitter acquisition and track equipment fabrication cost
PLTCQR	Plot receiver acquisition and track equipment fabrication cost
PLTCX	Plot transmitter fabrication cost
PLTCH	Plot transmitter heat exchanger fabrication cost
PLTCM	Plot modulation equipment fabrication cost
PLTCD	Plot demodulation equipment fabrication cost
PLTCST	Plot transmitter power supply fabrication cost
PLTCSR	Plot receiver power supply fabrication cost
PLTCA	Plot transmitter system fabrication cost
PLTCB	Plot receiver system fabrication cost
PLTCTO	Plot transmitter antenna cost burden
PLTCRO	Plot receiver antenna cost burden

TABLE IV-I (continued)
COMPLETE LISTING OF COPTRAN INSTRUCTION MNEMONICS

PLTCQO	Plot receiver field of view cost burden
PLTCGO	Plot transmitter power cost burden
PLTCV	Plot optimization cost
PLTCS	Plot total system cost
PLTWTH	Plot WORTH. (See Section 4. 3. 2.)

13. Instruction End

a) The "WORTH" program may be used if desired before instruction end. (See section 4. 3. 2 for the WORTH programming description and instruction.)

WORTH (Name)	Output parameter

b) The end instruction card, ENDINS, must be placed at the end of COPTRAN instructions.

ENDINS

14. Data and Data End

a) Any of the data constants of Table IV-II may be changed as desired. (COPTRAN coding sheets B and C, Figures 4-4 and 4-5, may be used to facilitate these changes.)

b) The "increment" program may be used if desired. (See section 4. 3. 4 for the increment programing description and instruction)

NCRMNT	XXX E±XX
(Data Name)	XXX E±XX
FINALE	XXX E±XX

c) An ENDDAT card must be used following a) and b) above.

ENDDAT

15. Case End

a) Before the case end card is used the REPEAT program may be used if desired. (See section 4. 3. 5 for the REPEAT programming description and instruction.)

b) REPEAT. The end case card, ENDCAS, must physically be the last card of the COPTRAN deck, following all instructions and data for all cases run.

ENDCAS

4.3.2 WORTH Program. — In order to facilitate the evaluation of the effect of varying system parameters, an additional feature, called WORTH, is available to the COPTRAN user. The instruction is used in conjunction with an NCRMNT set or a series of REPEAT runs. It is used by giving the instruction sequence:

WORTH
(NAME)

Here, (NAME) is the name of the output parameter (such as total system cost, CS) to be evaluated. This causes the COPTRAN system to save the results of the next set of runs (up to four as a maximum) for comparison. At the end of the series of runs, the differences between pairs of runs in all combinations are available. Thus, if B_i is the set of results for the parameter selected, B_i from the ith run, then, WORTH causes the system to compute the values

$$\Delta ij = B_i - B_j \quad (i>j).$$

The user can cause the results to be printed in a table by including the instruction, PRTWTH, in his program. The instruction, PLTWTH, causes the worth parameter B_i from each case to be plotted on a single set of axes. This is then followed by separate plots of each set of Δij, defined above..

The following rules apply to the use of the WORTH instruction (see Figure 4-4 and 4-5 for examples of its use):

1. The WORTH parameter, (NAME), must be the next instruction following the WORTH instruction.
2. The WORTH parameter must be one of the set of optimization output parameters listed in Table IV-II.
3. If NCRMNT is used to generate the series of cases, then the WORTH output is done on completion of the last NCRMNT iteration. If the REPEAT feature is used, WORTH output is done after the last REPEATED case. (Note that this precludes the use of REPEAT <u>and</u> NCRMNT together in conjunction with the WORTH instruction.)
4. If antenna optimization is done on gain (receiver and transmitter), then the WORTH parameter may not be diameter (receiver or

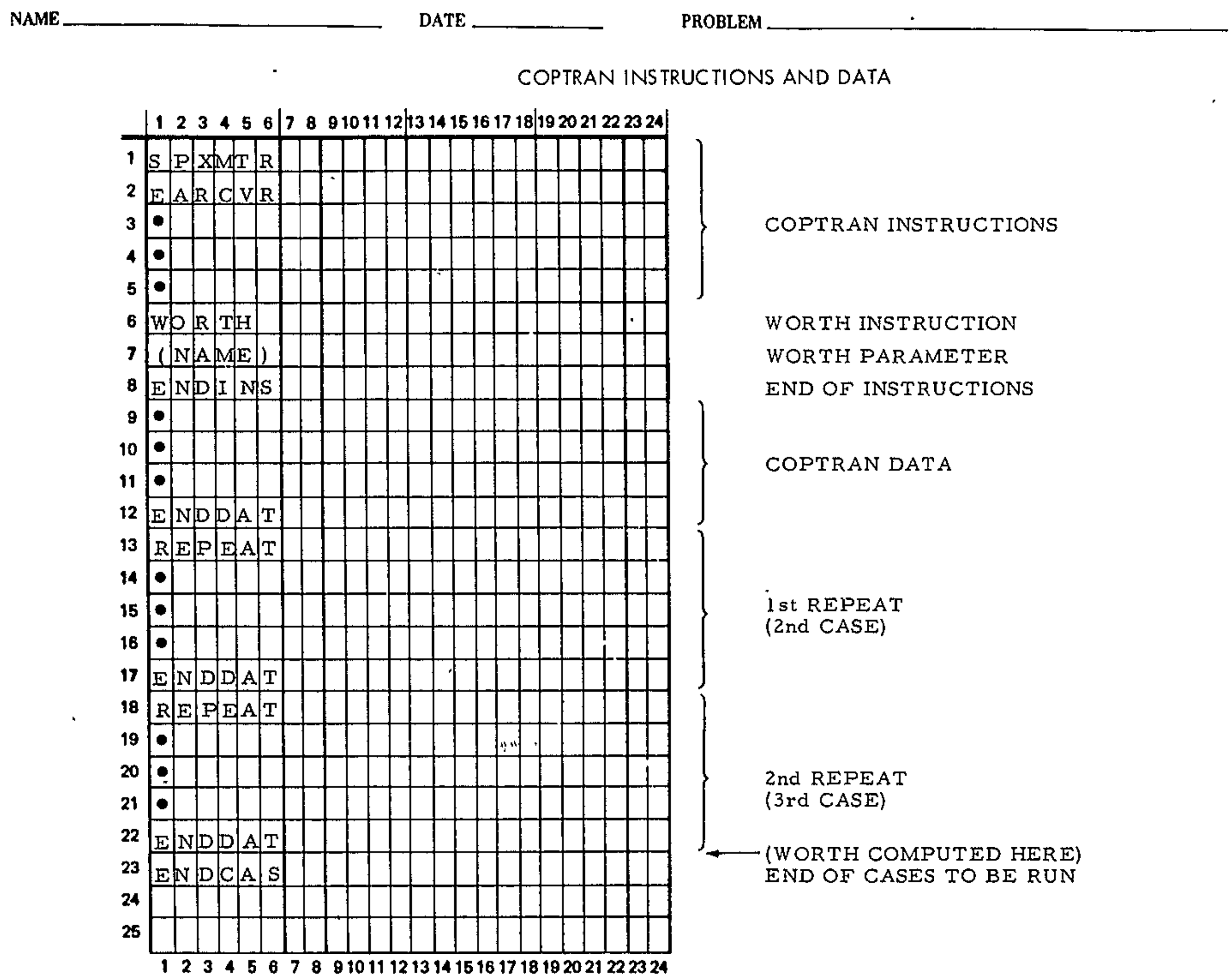

Figure 4-4. COPTRAN Coding Sheets Illustrating "WORTH"

NAME ____________________ DATE __________ PROBLEM ____________________

COPTRAN INSTRUCTIONS AND DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	S	P	X	M	T	R																			
2	E	A	R	C	V	R																			
3	•																								COPTRAN INSTRUCTIONS
4	•																								
5	•																								
6	W	O	R	T	H																				WORTH INSTRUCTIONS
7	(	N	A	M	E	)																			WORTH PARAMETER
8	E	N	D	I	N	S																			END OF INSTRUCTIONS
9	•																								
10	•																								COPTRAN DATA
11	•																								
12	N	C	R	M	N	T							Y	.	Y	Y			E	±	Y	Y			
13	(	D	A	T	A		N	A	M	E	)		Y	.	Y	Y			E	±	Y	Y			NCRMNT SET
14	F	I	N	A	L	E							Y	.	Y	Y			E	±	Y	Y			
15	E	N	D	D	A	T																			END OF DATA
16	•																								WORTH COMPUTED HERE
17	•																								
18	•																								
19	E	N	D	C	A	S																			END OF CASES TO BE RUN
20																									
21																									
22																									
23																									
24																									
25																									

Figure 4-5. COPTRAN Coding Sheets Illustrating "NCRMNT"

transmitter, respectively). Conversely, if diameter optimization is done, gain output parameters cannot requested for WORTH.

If any of the above rules are violated, error messages will be printed out (see section 4. 3. 6).

TABLE IV-II
WORTH PARAMETERS

Name	Description
WDT	transmitter antenna weight
WDR	receiver antenna weight
WQT	transmitter acquisition and track equipment weight
WQR	receiver acquisition and track equipment weight
WX	transmitter weight
WH	transmitter heat exchanger weight
WM	modulation equipment weight
WD	demodulation equipment weight
WST	transmitter power supply weight
WSR	receiver power supply weight
WA	total transmitter weight for optimum system parameters
WB	total receiver weight for optimum system parameters
PQT	transmitter acquisition and track equipment power requirement
PQR	receiver acquisition and track equipment power requirement
PX	transmitter power
PM	modulation equipment power requirement
PD	demodulation equipment power requirement
PA	total transmitter power requirement for optimum system parameters
PB	total receiver power requirements for optimum system parameters
CDT	transmitter antenna cost

TABLE IV-II (continued)
WORTH PARAMETERS

Name	Description
CDR	receiver antenna cost
CQT	transmitter acquisition and track equipment cost
CQR	receiver acquisition and track equipment cost
CX	transmitter cost
CH	heat exchanger fabrication cost
CM	modulation equipment cost
CD	demodulation equipment cost
CST	transmitter power supply cost
CSR	receiver power supply cost
CA	total transmitter cost for optimum system parameters
CB	total receiver cost for optimum system parameters
CTO	cost of transmitter antenna, transmitter acquisition and track equipment, and associated power supply which is dependent on transmitter aperture diameter, for optimum system parameters
CRO	cost of receiver antenna, receiver acquisition and track equipment and associated power supply which is dependent on receiver aperture diameter, for optimum system parameters.
CQO	cost of receiver acquisition and track equipment which is dependent on receiver field of view, for optimum system parameters.
CGO	cost of transmitter, transmitter power supply, and transmitter heat exchanger which is dependent on transmitter power, for optimum system parameters
CV	variable part of total system cost (optimization cost)
CS	total system cost
PTO	optimum value of transmitter power

TABLE IV-II (continued)
WORTH PARAMETERS

Name	Description
DTO	optimum value of transmitter aperture diameter
THERO	optimum value of receiver field of view
DRO	optimum value of receiver aperture diameter
GTO	optimum value of transmitter gain
GRO	optimum value of receiver gain

4.3.3 <u>COPTRAN data format</u>. – COPTRAN data is in two parts, a label consisting of up to six characters and a field consisting of up to fourteen characters in either fixed or floating point form. Small amounts of data are usually entered on COPTRAN Coding Sheet A (see Figure 4-3) by the user for subsequent key punching with the COPTRAN instructions. If a large amount of data is to be entered, COPTRAN Coding Sheets B and C shown in Figures 4-6 and 4-7 respectively may be utilized. These coding sheets contain preprinted data labels. Each data parameter will be punched on a single card, the total of these cards is the COPTRAN Data Deck. (Section 4.7 contains blank forms which are convenient for recoding large amounts of data.)

The data label must be justified left in columns 1 to 6 on the coding sheet. Columns 7, 8, 23, and 24 are left blank. The data value is entered in columns 9 to 22. Columns 25 to 80 may be employed for users comments.

Examples of fixed and floating point entries in the data field are given below. The decimal point in both cases is always in column 14.

Floating point entry: 7.5×10^{13}

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
						7	.	5				E.	+	1	3		

Fixed point entry: 0.95

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
							.	9	5								

COPTRAN CODING SHEET B

NAME ________________ DATE ________ PROBLEM ________________

SYSTEM BURDENS DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	K	T	H	T										.										
2	K	D	T											.										
3	C	K	T											.										
4	W	K	T											.										
5	M	T												.										
6	N	T												.										
7																								
8	K	A	T											.										
9	K	W	A	T										.										
10	K	P	Q	T										.										
11	C	A	T											.										
12	W	B	T											.										
13	Q	T												.										
14																								
15	K	F	M											.										
16	K	M												.										
17	K	P	M											.										
18	C	K	M											.										
19	W	K	M											.										
20																								
21	K	S	T											.										
22	K	W	S	T										.										
23	C	K	E											.										
24	W	K	E											.										
25																								

SYSTEM BURDENS DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	K	T	H	R										.										
2	K	D	R											.										
3	C	K	R											.										
4	W	K	R											.										
5	M	R												.										
6	N	R												.										
7																								
8	K	A	R											.										
9	K	W	A	R										.										
10	K	P	Q	R										.										
11	C	A	R											.										
12	W	B	R											.										
13	Q	R												.										
14																								
15	K	F	D											.										
16	K	D												.										
17	K	P	D											.										
18	C	K	D											.										
19	W	K	D											.										
20																								
21	K	S	R											.										
22	K	W	S	R										.										
23	C	K	F											.										
24	W	K	F											.										
25																								

Figure 4-6. COPTRAN Coding Sheet B

COPTRAN CODING SHEET C

NAME ______________________ DATE ____________ PROBLEM ______________________________

SYSTEM BURDENS DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	K	P	T											.										
2	K	W	T											.										
3	K	H												.										
4	K	X												.										
5	K	E												.										
6	C	K	P											.										
7	C	K	H											.										
8	W	K	P											.										
9	W	K	H											.										
10	G	T												.										
11	H	T												.										
12	J	T												.										
13																								
14	K	S	A											.										
15	K	S	B											.										
16																								
17																								
18																								
19																								
20																								
21																								
22																								
23																								
24																								
25																								

SYSTEM PHYSICAL DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	R													.										
2	L	A	M	B	D	A								.										
3	S	N												.										
4	C	N												.										
5	U	S	B	R	E	Q								.										
6	T	A	U	T										.										
7	T	A	U	R										.										
8	T	A	U	A										.										
9	T	E												.										
10	E	T	A											.										
11	R	L												.										
12	L	M	B	D	I									.										
13	Q	B												.										
14																								
15																								
16																								
17																								
18																								
19																								
20																								
21																								
22																								
23																								
24																								
25																								

Figure 4-7. COPTRAN Coding Sheet C

A control card with the characters ENDDAT in columns 1 to 6 must be placed at the end of the COPTRAN Data Deck. This card is required even if there are no new data entries: If any item of data is not included in the COPTRAN Data Deck by the user, the COPTRAN program automatically selects the value of the data item from the nominal value data bank. The labels and definitions of the COPTRAN data which may be used are listed in Table IV-III.

TABLE IV-IIIa
COPTRAN DATA

System Physical Data   Choose as desired

Label	Description
R	Transmission range
LAMBDA	Transmission wavelength
SN	Signal-to-noise power ratio
CN	Carrier-to-background radiation power ratio
USBREQ	Required signal photoelectron count per bit
TAUT	Transmitter transmissivity
TAUR	Receiver transmissivity
TAUA	Atmospheric transmissivity
RHOT	Transmitter antenna efficiency
RHOR	Receiver antenna efficiency
TE	Receiver equivalent temperature
ETA	Detector quantum efficiency
RL	Receiver output load resistance
LMBDI	Optical filter bandwidth
QB	Background radiation photon spectral radiance
PER	Required probability of detection error

TABLE IV-IIIb
COPTRAN DATA

Systems Burdens Data   Choose as desired

Symbol	Description
KTHT	Constant Relating Transmitter Antenna Fabrication Cost to Transmitter Antenna Diameter
KDT	Constant Relating Transmitter Antenna Weight to Transmitter Antenna Diameter
CKT	Transmitter Antenna Fabrication Cost Independent of Transmitter Antenna Diameter
WKT	Transmitter Antenna Weight Independent of Transmitter Antenna Diameter
MT	Exponent Relating Transmitter Antenna Fabrication Cost to Transmitter Antenna Diameter
NT	Exponent Relating Transmitter Antenna Weight to Transmitter Antenna Diameter
KAT	Constant Relating Transmitter Acquisition — Track Equipment Fabrication Cost to Transmitter Beamwidth
KWAT	Constant Relating Transmitter Acquisition — Track Equipment Weight to Transmitter Antenna Weight
KPQT	Constant Relating Transmitter Acquisition — Track Equipment Power Requirement to Weight
CAT	Transmitter Acquisition — Track Equipment Fabrication Cost Independent of Transmitter Beamwidth
WBT	Transmitter Acquisition — Track Equipment Weight Independent of Transmitter Beamwidth
QT	Exponent Relating Transmitter Acquisition — Track Equipment Fabrication Cost to Transmitter Beamwidth
KFM	Constant Relating Modulation Equipment Fabrication Cost to Information Rate
KM	Constant Relating Modulation Equipment Weight to Information Rate
KPM	Constant Relating Modulation Equipment Power Requirement to Information Rate
CKM	Modulation Equipment Fabrication Cost Independent of Information Rate
WKM	Modulation Equipment Weight Independent of Information Rate
KST	Constant Relating Transmitter Power Supply Fabrication Cost to Power Requirement

TABLE IV-IIIb (continued)
COPTRAN DATA

Systems Burdens Data   Choose as desired

Symbol	Description
KWST	Constant Relating Transmitter Power Supply Weight to Power Requirement
CKE	Transmitter Power Supply Fabrication Cost Independent of Power Requirement
WKE	Transmitter Power Supply Weight Independent of Power Requirement
KTHR	Constant Relating Receiver Antenna Fabrication Cost to Receiver Antenna Diameter
KDR	Constant Relating Receiver Antenna Weight to Receiver Antenna Diameter
CKR	Receiver Antenna Fabrication Cost Independent of Receiver Antenna Diameter
WKR	Receiver Antenna Weight Independent of Receiver Antenna Diameter
MR	Exponent Relating Receiver Antenna Fabrication Cost to Receiver Antenna Diameter
NR	Exponent Relating Receiver Antenna Weight to Receiver Antenna Diameter
KAR	Constant Relating Receiver Acquisition — Track Equipment Fabrication Cost to Receiver Beamwidth
KWAR	Constant Relating Receiver Acquisition — Track Equipment Weight to Receiver Antenna Weight
KPQR	Constant Relating Transmitter Acquisition — Track Equipment Power Requirement to Weight
CAR	Receiver Acquisition — Track Equipment Fabrication Cost Independent of Receiver Beamwidth
WBR	Exponent Relating Receiver — Track Equipment Fabrication Cost to Receiver Beamwidth
QR	Exponent Relating Receiver Track Equipment Fabrication Cost to Receiver Beamwidth
KFD	Constant Relating Demodulation Equipment Fabrication Cost to Information Rate
KD	Constant Relating Demodulation Equipment Weight to Information Rate
KPD	Constant Relating Demodulation Equipment Power Requirement to Information Rate

TABLE IV-IIIb (continued)
COPTRAN DATA

Systems Burdens Data   Choose as desired

Symbol	Description
CKD	Demodulation Equipment Fabrication Cost Independent of Information Rate
WKD	Demodulation Equipment Weight Independent of Information Rate
KSR	Constant Relating Receiver Power Supply Fabrication Cost to Power Requirement
KWSR	Constant Relating Receiver Power Supply Weight to Power Requirement
CKF	Receiver Power Supply Fabrication Cost Independent of Power Requirement
WKF	Receiver Power Supply Weight Independent of Power Requirement
KPT	Constant Relating Transmitter Fabrication Cost to Transmitter Power
KWT	Constant Relating Transmitter Weight to Transmitter Power
KH	Constant Relating Transmitter Heat Exchanger Fabrication Cost to Transmitter Power Dissipation
KX	Constant Relating Transmitter Heat Exchanger Weight to Transmitter Power Dissipation
KE	Transmitter Power Efficiency
CKP	Transmitter Fabrication Cost Independent of Transmitter Power
CKH	Transmitter Heat Exchanger Fabrication Cost Independent of Transmitter Power
WKP	Transmitter Weight Independent of Transmitter Power
WKH	Transmitter Heat Exchanger Weight Independent of Transmitter Power
GT	Exponent Relating Transmitter Fabrication Cost to Transmitter Power
HT	Exponent Relating Transmitter Weight to Transmitter Power
JT	Exponent Relating Transmitter Power Supply-Heat Exchanger Burdens to Transmitter Power
KSA	Cost per Unit Weight for Spaceborne Transmitter System Equipment
KSB	Cost per Unit Weight for Spaceborne Receiver System Equipment

TABLE IV-IIIc
COPTRAN DATA

Major System Parameter Constraints — Choose as indicated below

	Label	Description
A.	DTM	Fixed value of transmitter antenna diameter
A.	GTM	Fixed value of transmitter antenna gain
B.	DRM	Fixed value of receiver antenna diameter
B.	GRM	Fixed value of receiver antenna gain
	PTM	Fixed value of transmitter power
	THERM	Fixed value of receiver field of view
A.	DTB	Stop value of transmitter antenna diameter
A.	GTB	Stop value of transmitter antenna gain
B.	DRB	Stop value of receiver antenna diameter
B.	GRB	Stop value of receiver antenna gain
	PTB	Stop value of transmitter power
	THERB	Stop value of receiver field of view
C.	DTI	Initial value of transmitter antenna diameter
C.	GTI	Initial value of transmitter antenna gain
C.	DRI	Initial value of receiver antenna diameter
C.	GRI	Initial value of receiver antenna gain
C.	PTI	Initial value of transmitter power
	THERI	Initial value of receiver field of view

A. Choose DTM (DTB) for transmitter antenna diameter optimization and GTM (GTB) for transmitter antenna gain optimization.

B. Choose DRM (DRB) for receiver antenna diameter optimization and GRM (GRB) for receiver antenna gain optimization.

C. Initial values of the system parameters may be chosen, if desired, to speed the convergence to a solution by the COPS program.

4.3.4 Increment Program. — NCRMNT (mnemonic for increment) — This instruction set permits the user to specify a series of runs in which one data value is varied from an initial value to a final value in finite step sizes. Figure 4-8 shows the three instructions and their use. The sequence

NCRMNT	XXX E±XX
(DATA NAME)	XXX E±XX
FINALE	XXX E±XX

will cause a series of COPS runs to be made in which the variable named (DATA NAME) assumes the values from that on the (DATA NAME) card to that on the FINALE card in step sizes specified on the NCRMNT card. The variable (DATA NAME) will be incremented until its value is strictly greater than the final value specified. When this condition occurs, control returns to the COPTRAN processor and the case is finished.

NAME ______________ DATE ________ PROBLEM ______________________

COPTRAN INSTRUCTIONS AND DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	S	P	X	M	T	R																			
2	E	A	R	C	V	R																			
3	o																								
4	o																								
5	o																								COPTRAN INSTRUCTIONS AND DATA
6	E	N	D	I	N	S																			
7	o																								
8	o																								
9	o																								
10	N	C	R	M	N	T							Y	•	Y			E	±	Y	Y				(STEP SIZE)
11	(	D	A	T	A		N	A	M	E	)		Y	•	Y	Y		E	±	Y	Y				(INITIAL VALUE)
12	F	I	N	A	L	E							Y	•	Y			E	±	Y	Y				(FINAL VALUE)
13	E	N	D	A	T																				END OF DATA
14	E	N	D	C	A	S																			END OF CASES TO BE RUN
15																									
16																									
17																									
18																									
19																									
20																									
21																									
22																									
23																									
24																									
25																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	

NOTE: Final value must be greater than initial value. All three cards must be present.

Figure 4-8. Increment (NCRMNT) Example.

4.3.5 Repeat Program. – REPEAT – This instruction signals the COPTRAN processor that more data or instructions follow which will be used to modify the case just completed. The cards following the REPEAT and preceding the next REPEAT or ENDCAS card will affect only those variables or instructions mentioned. As in normal COPTRAN programming, instructions must be terminated by an ENDINS card and precede all data. Data must be terminated by an ENDDAT card. Refer to Figure 4-9 for an example of the use of this feature.

Instructions following a REPEAT, override all instructions in the same COPTRAN instruction category from previous runs. Here category is defined to mean a group of similar instructions such as those referring to transmission range (category 3)* of those referring to optimization basis (category 7).* Data entries of the previous run remain in effect unless specifically named in the REPEAT sequence.

---

*See Table IV-I

NAME ____________ DATE ________ PROBLEM ____________________

COPTRAN INSTRUCTIONS AND DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	S	P	X	M	T	R																			
2	E	A	R	C	V	R																			
3	•																								
4	•																								COPTRAN PROGRAM
5	•																								
6	E	N	D	D	A	T																			
7	R	E	P	E	A	T																			REPEAT
8	X	X	X	X	X	X																			(NEW INSTRUCTION(S)
9	E	N	D	I	N	S																			END OF NEW INSTRUCTIONS
10	X	X	X	X	X	X							Y	•	Y	Y			E		Y	Y			(NEW DATA)
11	E	N	D	D	A	T																			END OF NEW DATA
12	R	E	P	E	A	T																			REPEAT
13	X	X	X	X	X	X																			(NEW INSTRUCTION(S)
14	E	N	D	I	N	S																			END OF NEW INSTRUCTIONS
15	X	X	X	X	X	X							Y	•	Y	Y			E		Y	Y			(NEW DATA)
16	E	N	D	D	A	T																			END OF NEW DATA
17	•																								
18	•																								
19	•																								
20	E	N	D	C	A	S																			END OF CASES TO BE RUN
21																									
22																									
23																									
24																									
25																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	

NOTE: Either new instructions or new data, or both, may follow a REPEAT.

Figure 4-9. "REPEAT" example.

4.3.6 Error Messages. — As mentioned before, certain COPTRAN instruction combinations are either invalid or not yet implemented in the COPTRAN system. When such combinations are encountered, appropriate messages will be printed for the user and the job will not be run. The error messages are listed below:

'nnnnnn' NOT YET IMPLEMENTED
where nnnnnn is the name of the illegal instruction mnemonic

THE ONLY BURDENS AVAILABLE WITH 'PCM/AM' and 'PCM/FM' ARE FOR 'LAM106'

THE ONLY BURDENS AVAILABLE WITH 'PCM/PL' ARE FOR 'LAM051'

THE ONLY BURDENS AVAILABLE WITH 'PCM/PM' ARE FOR 'LAM13C'

THE ONLY BURDENS AVAILABLE WITH 'OPTDIR' ARE FOR 'PCM/PL' AND 'LAM051'

THE ONLY BURDENS AVAILABLE WITH 'OPTHET' ARE FOR 'PCM/FM' AND 'LAM106'

THE ONLY BURDENS AVAILABLE WITH 'RADHOM' ARE FOR 'PCM/PM' AND 'LAM13C'

IF 'DRM' AND 'THERM' OR 'DTM' AND 'PTM' ARE NOT OPTIMIZED IN WEIGHT OR COST, FIXED VALUES MUST BE GIVEN

'mmmmmm' SHOULD ONLY BE USED WITH RADIO SYSTEMS
where mmmmmm is GTDROP, DTGROP, or GTGROP.

'xxxxxx' NOT VALID WORTH PARAMETER. WORTH DELETED
where xxxxxx is the instruction following the WORTH command.

'yyyyyy' IS NOT A VALID WORTH PARAMETER WITH 'zzzzzz'

where yyyyyy and zzzzzz will appear in pairs as follows:

yyyyyy	zzzzzz
GT	DTDROP
GT	DTGROP
GR	DTDROP
GR	GTDROP
DT	GTDTROP
DT	GTGROP
DR	DTGROP
DR	GTGROP

4.4 Program Examples

The following pages contain four examples of COPTRAN use. Each example contains a short description of the problem followed by a COPTRAN coding sheet as it might be coded for that problem. The output from that COPTRAN program concludes the data for a particular example.

Example A. Synchronous Satellite Transmitter to Earth Receiver Link

10.6 micron wavelength

PCM Intensity Modulation and Optical Direct Detection Receiver

Thermal Noise Limited Operation

Transmitter system weight and fabrication cost, and receiver fabrication cost jointly optimized.

Parameters to be optimized:

a. Transmitter antenna diameter
b. Receiver antenna diameter
c. Transmitter power

Fixed Parameters: Receiver field of view at 1 milliradian

Parameter Stops: None

NAME ______________ DATE ________ PROBLEM EXAMPLE A

COPTRAN INSTRUCTIONS AND DATA

INSTRUCTION TYPE*		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	1	S	P	X	M	T	R																			SPACECRAFT TRANSMITTER
2	2	E	A	R	C	V	R																			EARTH RECEIVER
3	3	R	A	N	S	A	T																			SYNCHRONOUS SATELLITE RANGE
4	4	L	A	M	1	0	6																			10.6 MICRON TRANSMISSION WAVELENGTH
5	5	B	K	D	S	K	Y																			DAY SKY BACKGROUND
6	6	P	C	M	/	A	M																			PCM INTENSITY MODULATION
6	7	O	P	T	D	I	R																			OPTICAL DIRECT DETECTION
7	8	X	M	W	T	O	P																			TRANSMITTER SYSTEM WEIGHT AND
7	9	X	M	F	C	O	P																			FABRICATION COST AND RECEIVER SYSTEM
7	10	R	C	F	C	O	P																			FABRICATION COST OPTIMIZATION
8	11	D	T	D	R	O	P																			XMTR & RCVR ANT DIAMETER OPTIMIZATION
10	12	R	B	F	R	Q	2																			DATA POINTS AT $R_B = 10^2$, 0.5×10^3, 10^3,
10	13	R	B	I	N	T	2																			. . . , 10^8 BPS
10	14	R	B	F	I	N	8																			
11	15	P	R	T	A	L	L																			PRINT ALL DATA VALUES ANDRESULTS OF OPT.
12	16	P	L	T	O	P	T																			PLOT RESULTS OF OPTIMIZATION
13	17	E	N	D	I	N	S																			END OF COPTRAN INSTRUCTIONS
DATA	18	T	H	E	R	M								1	•	0				E	—	0	3			1 MILLIRADIAN FIELD OF VIEW
14	19	E	N	D	D	A	T																			END OF COPTRAN DATA
15	20	E	N	D	C	A	S																			END OF COPTRAN CASES
	21																									
	22																									
	23																									
	24																									
	25																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
SYNCHRONOUS SATELLITE RANGE(3.6E4 KM)
TRANSMISSION WAVELENGTH LAMBDA = 10.6 MICRONS
DAY SKY BACKGROUND
PCM AMPLITUDE MODULATION
OPTICAL DIRECT DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
RECEIVER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA DIAMETER AND RECEIVER ANTENNA DIAMETER OPTIMIZATION


*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
RANSAT
CAM106
BKDSKY
PCM/AM
OPTDIR
XMWTOP
XMFCOP
RCFCOP

DTDROP
RBFR02
RBINT2
RBFIN8
PRTACL
PLTOPT
ENDINS
THERM          1.0    E-03
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	KTHT	14.00000	KDT	0.01000	CKT	20000.00	WKT	25.00	MT	2.00	NT	2.00000
RECEIVER ANTENNA	KTHR	8.75000	KDR	0.0230000	CKR	25000.00	WKR	20.00000	MR	2.00000	NR	2.00000
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.46000	KPQT	0.48000	CAT	400000.	WBT	5.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	71000.	KWAR	0.46000	KPQR	0.48000	CAR	200000.	WBR	5.000	QR	0.30000
TRANSMITTER	KPT	1.43000	KWT	2.00000	KH	1.97000	KX	0.02500	KE	0.10000	CKP	2000.00
	CKH	13800.	WKP	25.000	WKH	0.	JT	1.000	G1	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.00050	KM	0.00000	KPM	5.00000	CKM	15000.	WKM	10.00		
DEMODULATION EQUIPMENT	KFD	0.0000550	KD	0.00000011	KPD	3.33000	CKD	15000.	WKD	30.000		
TRANSMITTER POWER SUPPLY	KST	166.000	KWST	0.157000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

SYSTEM PHYSICAL DATA

R	0.36000E 10	LAMBDA	0.10600E-02	S/N	0.26000E 02	C/N	0.60000E 01	USBREQ	0.30000E 02	TAU-T	0.80000E 00
TAU-R	0.70000E 00	TAU-A	0.80000E 00	TE	0.30000E 03	ETA	0.50000E 00	RL	0.10000E 03	LMBD-I	0.10000E-02
QB	0.	RHO-T	0.98000E 00	RHO-R	0.98000E 00						

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.	KM	0.36017E-06	KR	0.	KS	0.

SYSTEM BURDEN CONSTANTS

KMT	0.14000E 02	KNT	0.24879E 02	KQT	0.55420E 06	KMR	0.87500E 01	KNR	0.12696E 00	KQR	0.71000E 05
KGT	0.14300E 01	KHT	0.32800E 04	KJT	0.46215E 04						

PARAMETER CONSTRAINTS

DTI	0.50000E 02	GTI	0.	DRI	0.50000E 03	GRI	0.	PTI	0.25000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.	PTM	0.	THERM	0.10000E-02
DTB	0.10000E 03	GTB	0.	DRB	0.10000E 04	GRB	0.	PTB	0.50000E 03	THERB	0.10000E-02

OPTIMIZATION RESULTS

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INFORMATION RATE,RB 0.10000E 09

OPTIMUM SYSTEM PARAMETERS			DTO	0.712299E 01	DRO	0.130764E 03	PTO	0.192065E 02	THERO	0.1000E-02
OPTIMUM WEIGHT BURDENS	WDT	0.255074E 02	WDR	0.413279E 03	WOT	0.523339E 01	WOR	0.185908E 03	WX	0.634130E 02
	WH	0.432146E 01	WM	0.400000E 02	WD	0.410000E 02	WST	0.619485E 02	WSR	0.
	WA	0.200424E 03	WB	0.640188E 03						
OPTIMUM POWER BURDENS	POT	0.251203E 01	POR	0.892361E 02	PX	0.192065E 03	PM	0.200000E 03	PD	0.136530E 03
	PA	0.394577E 03	PB	0.225766E 03						
OPTIMUM FABRICATION COST BURDENS			CDT	0.207103E 05	CDR	0.174617E 06	COT	0.139877E 07	COR	0.763973E 06
	CX	0.202747E 04	CH	0.141405E 05	CM	0.650000E 05	CD	0.205000E 05	CST	0.654997E 05
	CSR	0.156442E 05	CA	0.156615E 07	CB	0.974734E 06				
OPTIMUM SYSTEM COST BURDENS			CTO	0.100074E 07	CRO	0.151788E 06	COO	0.563973E 06	CGO	0.151788E 06
	CV	0.186829E 07	CS	0.391948E 07						

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INFORMATION RATE,RB 0.50001E 08

OPTIMUM SYSTEM PARAMETERS			DTO	0.624660E 01	DRO	0.128047E 03	PTO	0.184167E 02	THERO	0.1000E-02
OPTIMUM WEIGHT BURDENS	WDT	0.253902E 02	WDR	0.397107E 03	WOT	0.517949E 01	WOR	0.178469E 03	WX	0.618334E 02
	WH	0.414376E 01	WM	0.250003E 02	WD	0.355001E 02	WST	0.489298E 02	WSR	0.
	WA	0.170477E 03	WB	0.611077E 03						
OPTIMUM POWER BURDENS	POT	0.248616E 01	POR	0.856653E 02	PX	0.184167E 03	PM	0.125002E 03	PD	0.118215E 03
	PA	0.311655E 03	PB	0.203881E 03						
OPTIMUM FABRICATION COST BURDENS			CDT	0.205463E 05	CDR	0.168465E 06	COT	0.136020E 07	COR	0.763973E 06
	CX	0.202634E 04	CH	0.141265E 05	CM	0.400006E 05	CD	0.177501E 05	CST	0.517347E 05
	CSR	0.150970E 05	CA	0.148863E 07	CB	0.965285E 06				
OPTIMUM SYSTEM COST BURDENS			CTO	0.961712E 06	CRO	0.145546E 06	COO	0.563973E 06	CGO	0.145546E 06
	CV	0.181678E 07	CS	0.373566E 07						

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INFORMATION RATE,RB    0.10000E 08
OPTIMUM SYSTEM PARAMETERS              DTO    0.459875E 01  DRO    0.122039E 03  PTO    0.167290E 02  THERO    0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT    0.252115E 02  WDR    0.362549E 03  WQT    0.509728E 01  WQR    0.162573E 03  WX    0.584580E 02
                        WH     0.376402E 01  WM     0.130000E 02  WD     0.311000E 02  WST    0.368536E 02  WSR   0.
                        WA     0.142384E 03  WB     0.556222E 03

OPTIMUM POWER BURDENS   PQT    0.244670E 01  PQR    0.780349E 02  PX     0.167290E 03  PM     0.649999E 02  PD    0.103563E 03
                        PA     0.234736E 03  PB     0.181598E 03

OPTIMUM FABRICATION COST BURDENS             CDT    0.202961E 05  CDR    0.155318E 06  CQT    0.127591E 07  CQR   0.763973E 06
                        CX     0.202392E 04  CH     0.140966E 05  CM     0.200000E 05  CD     0.155500E 05  CST   0.389663E 05
                        CSR    0.145399E 05  CA     0.137129E 07  CB     0.949381E 06

OPTIMUM SYSTEM COST BURDENS                  CTO    0.876731E 06  CRO    0.132208E 06  CQO    0.563973E 06  CGO   0.132208E 06
                        CV     0.170512E 07  CS     0.346639E 07

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INFORMATION RATE,RB    0.50001E 07
OPTIMUM SYSTEM PARAMETERS              DTO    0.402876E 01  DRO    0.119565E 03  PTO    0.160577E 02  THERO    0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT    0.251623E 02  WDR    0.348804E 03  WQT    0.507466E 01  WQR    0.156250E 03  WX    0.571155E 02
                        WH     0.361299E 01  WM     0.115000E 02  WD     0.305500E 02  WST    0.346206E 02  WSR   0.
                        WA     0.137086E 03  WB     0.535604E 03

OPTIMUM POWER BURDENS   PQT    0.243584E 01  PQR    0.750000E 02  PX     0.160577E 03  PM     0.575002E 02  PD    0.101732E 03
                        PA     0.220513E 03  PB     0.176732E 03

OPTIMUM FABRICATION COST BURDENS             CDT    0.202272E 05  CDR    0.150089E 06  CQT    0.124182E 07  CQR   0.763973E 06
                        CX     0.202296E 04  CH     0.140847E 05  CM     0.175001E 05  CD     0.152750E 05  CST   0.366052E 05
                        CSR    0.144183E 05  CA     0.133226E 07  CB     0.943755E 06

OPTIMUM SYSTEM COST BURDENS                  CTO    0.842448E 06  CRO    0.126904E 06  CQO    0.563973E 06  CGO   0.126904E 06
                        CV     0.166023E 07  CS     0.337922E 07

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INFORMATION RATE,RB     0.10000E 07
OPTIMUM SYSTEM PARAMETERS                  DTO    0.296094E 01  DRO    0.114052E 03  PTO    0.146110E 02  THERO   0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT    0.250877E 02  WDR    0.319181E 03  WUT    0.504033E 01  WQR    0.142623E 03   WX    0.542220E 02
                         WH    0.328748E 01   WM    0.103000E 02   WD    0.301100E 02  WST    0.314046E 02  WSR    0.
                         WA    0.129342E 03   WB    0.491914E 03

OPTIMUM POWER BURDENS   PUT    0.241936E 01  PQR    0.684592E 02   PX    0.146110E 03   PM    0.515000E 02   PD    0.100266E 03
                         PA    0.200030E 03   PB    0.168725E 03

OPTIMUM FABRICATION COST BURDENS             CDT    0.201227E 05  CDR    0.138819E 06  CUT    0.116753E 07  CQR    0.763973E 06
                         CX    0.202089E 04   CH    0.140591E 05   CM    0.155000E 05   CD    0.150550E 05  CST    0.332049E 05
                        CSR    0.142181E 05   CA    0.125244E 07   CB    0.932065E 06

OPTIMUM SYSTEM COST BURDENS                  CTO    0.767871E 06  CRO    0.115470E 06  COO    0.563973E 06  CGO    0.115470E 06
                         CV    0.156278E 07   CS    0.320336E 07

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INFORMATION RATE,RB     0.50001E 06
OPTIMUM SYSTEM PARAMETERS                  DTO    0.259263E 01  DRO    0.111769E 03  PTO    0.140318E 02  THERO   0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT    0.250672E 02  WDR    0.307322E 03  WOT    0.503092E 01  WQR    0.137168E 03   WX    0.530637E 02
                         WH    0.315717E 01   WM    0.101500E 02   WD    0.300550E 02  WST    0.303769E 02  WSR    0.
                         WA    0.126846E 03   WB    0.474545E 03

OPTIMUM POWER BURDENS   PUT    0.241484E 01  PQR    0.658406E 02   PX    0.140318E 03   PM    0.507500E 02   PD    0.100083E 03
                         PA    0.193483E 03   PB    0.165924E 03

OPTIMUM FABRICATION COST BURDENS             CDT    0.200941E 05  CDR    0.134307E 06  CUT    0.113755E 07  CQR    0.763973E 06
                         CX    0.202007E 04   CH    0.140488E 05   CM    0.152500E 05   CD    0.150275E 05  CST    0.321182E 05
                        CSR    0.141481E 05   CA    0.122108E 07   CB    0.927456E 06

OPTIMUM SYSTEM COST BURDENS                  CTO    0.737807E 06  CRO    0.110893E 06  COO    0.563973E 06  CGO    0.110893E 06
                         CV    0.152357E 07   CS    0.313481E 07

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INFORMATION RATE,RB    0.10000E 06
OPTIMUM SYSTEM PARAMETERS             DTO   0.190389E 01  DRO   0.106659E 03  PTO   0.127781E 02  THERO   0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT   0.250362E 02  WDR   0.281650E 03  WQT   0.501667E 01  WQR   0.125359E 03  WX   0.505563E 02
                         WH   0.287508E 01   WM   0.100300E 02   WD   0.300110E 02  WST   0.283133E 02  WSR  0.
                         WA   0.121828E 03   WB   0.437020E 03

OPTIMUM POWER BURDENS   PQT   0.240800E 01  PQR   0.601723E 02   PX   0.127781E 03   PM   0.501500E 02  PD   0.999366E 02
                         PA   0.180339E 03   PB   0.160109E 03

OPTIMUM FABRICATION COST BURDENS            CDT   0.200507E 05  CDR   0.124541E 06  CQT   0.107229E 07  CQR  0.763973E 06
                         CX   0.201827E 04   CH   0.140266E 05   CM   0.150500E 05   CD   0.150055E 05  CST  0.299363E 05
                        CSR   0.140027E 05   CA   0.115338E 07   CB   0.917522E 06

OPTIMUM SYSTEM COST BURDENS                 CTO   0.672435E 06  CRO   0.100985E 06  CQO   0.563973E 06  CGO  0.100985E 06
                         CV   0.143838E 07   CS   0.298741E 07

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INFORMATION RATE,RB    0.50001E 05
OPTIMUM SYSTEM PARAMETERS             DTO   0.166667E 01  DRO   0.104536E 03  PTO   0.122746E 02  THERO   0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT   0.250278E 02  WDR   0.271339E 03  WQT   0.501278E 01  WQR   0.120616E 03  WX   0.495492E 02
                         WH   0.276178E 01   WM   0.100150E 02   WD   0.300055E 02  WST   0.275106E 02  WSR  0.
                         WA   0.119877E 03   WB   0.421960E 03

OPTIMUM POWER BURDENS   PQT   0.240613E 01  PQR   0.578957E 02   PX   0.122746E 03   PM   0.500750E 02  PD   0.999183E 02
                         PA   0.175227E 03   PB   0.157814E 03

OPTIMUM FABRICATION COST BURDENS            CDT   0.200389E 05  CDR   0.120618E 06  CQT   0.104598E 07  CQR  0.763973E 06
                         CX   0.201755E 04   CH   0.140176E 05   CM   0.150250E 05   CD   0.150028E 05  CST  0.290877E 05
                        CSR   0.139453E 05   CA   0.112617E 07   CB   0.913539E 06

OPTIMUM SYSTEM COST BURDENS                 CTO   0.646091E 06  CRO   0.970055E 05  CQO   0.563973E 06  CGO  0.970055E 05
                         CV   0.140408E 07   CS   0.292832E 07

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INFORMATION RATE,RB     0.10000E 05
OPTIMUM SYSTEM PARAMETERS                DTO    0.122344E 01  DRO    0.997762E 02  PTO    0.111822E 02  THERO    0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT    0.250150E 02  WDR    0.248972E 03  WQT    0.500689E 01  WQR    0.110327E 03   WX    0.473645E 02
                         WH    0.251600E 01   WM    0.100030E 02   WD    0.300011E 02  WST    0.257858E 02  WSR    0.
                         WA    0.115691E 03   WB    0.389300E 03

OPTIMUM POWER BURDENS   PQT    0.240330E 01  PQR    0.529570E 02   PX    0.111822E 03   PM    0.500150E 02   PD    0.999037E 02
                         PA    0.164241E 03   PB    0.152861E 03

OPTIMUM FABRICATION COST BURDENS             CDT    0.200210E 05  CDR    0.112109E 06  CQT    0.988764E 06  CQR    0.763973E 06
                         CX    0.201599E 04   CH    0.139983E 05   CM    0.150050E 05   CD    0.150005E 05  CST    0.272639E 05
                        CSR    0.138215E 05   CA    0.106707E 07   CB    0.904904E 06

OPTIMUM SYSTEM COST BURDENS                  CTO    0.588822E 06  CRO    0.883727E 05  CQO    0.563973E 06  CGO    0.883727E 05
                         CV    0.132954E 07   CS    0.280016E 07

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INFORMATION RATE,RB     0.50001E 04
OPTIMUM SYSTEM PARAMETERS                DTO    0.107087E 01  DRO    0.977961E 02  PTO    0.107428E 02  THERO    0.1000E-02

OPTIMUM WEIGHT BURDENS  WDT    0.250115E 02  WDR    0.239974E 03  WQT    0.500528E 01  WQR    0.106188E 03   WX    0.464856E 02
                         WH    0.241713E 01   WM    0.100015E 02   WD    0.300005E 02  WST    0.250946E 02  WSR    0.
                         WA    0.114016E 03   WB    0.376162E 03

OPTIMUM POWER BURDENS   PQT    0.240253E 01  PQR    0.509702E 02   PX    0.107428E 03   PM    0.500075E 02   PD    0.999018E 02
                         PA    0.159838E 03   PB    0.150872E 03

OPTIMUM FABRICATION COST BURDENS             CDT    0.200161E 05  CDR    0.108686E 06  CQT    0.965702E 06  CQR    0.763973E 06
                         CX    0.201536E 04   CH    0.139905E 05   CM    0.150025E 05   CD    0.150003E 05  CST    0.265331E 05
                        CSR    0.137718E 05   CA    0.104326E 07   CB    0.901431E 06

OPTIMUM SYSTEM COST BURDENS                  CTO    0.565747E 06  CRO    0.848999E 05  CQO    0.563973E 06  CGO    0.848999E 05
                         CV    0.129952E 07   CS    0.274858E 07

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INFORMATION RATE,RB      0.10000E 04
OPTIMUM SYSTEM PARAMETERS                DTO    0.785941E 00  DRO    0.933518E 02  PTO    0.978858E 01  THERO    0.1000E-02

OPTIMUM WEIGHT BURDENS   WDT    0.250062E 02  WDR    0.220435E 03  WQT    0.500284E 01  WQR    0.972000E 02  WX    0.445772E 02
                          WH    0.220243E 01   WM    0.100003E 02   WD    0.300001E 02  WST    0.235953E 02  WSR   0.
                          WA    0.110384E 03   WB    0.347635E 03

OPTIMUM POWER BURDENS    PQT    0.240136E 01  PQR    0.466560E 02   PX    0.978858E 02   PM    0.500015E 02   PD   0.999004E 02
                          PA    0.150289E 03   PB    0.146556E 03

OPTIMUM FABRICATION COST BURDENS              CDT    0.200086E 05  CDR    0.101252E 06  CQT    0.915565E 06  CQR   0.763973E 06
                          CX    0.201400E 04   CH    0.139736E 05   CM    0.150005E 05   CD    0.150001E 05  CST   0.249479E 05
                         CSR    0.136639E 05   CA    0.991510E 06   CB    0.893889E 06

OPTIMUM SYSTEM COST BURDENS                   CTO    0.515589E 06  CRO    0.773588E 05  CQO    0.563973E 06  CGO   0.773588E 05
                          CV    0.123428E 07   CS    0.263655E 07

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INFORMATION RATE,RB      0.50001E 03
OPTIMUM SYSTEM PARAMETERS                DTO    0.687896E 00  DRO    0.915017E 02  PTO    0.940443E 01  THERO    0.1000E-02

OPTIMUM WEIGHT BURDENS   WDT    0.250047E 02  WDR    0.212569E 03  WQT    0.500218E 01  WQR    0.935816E 02  WX    0.438089E 02
                          WH    0.211600E 01   WM    0.100001E 02   WD    0.300001E 02  WST    0.229920E 02  WSR   0.
                          WA    0.108924E 03   WB    0.336150E 03

OPTIMUM POWER BURDENS    PQT    0.240104E 01  PQR    0.449192E 02   PX    0.940443E 02   PM    0.500007E 02   PD   0.999002E 02
                          PA    0.146446E 03   PB    0.144819E 03

OPTIMUM FABRICATION COST BURDENS              CDT    0.200066E 05  CDR    0.982599E 05  CQT    0.895363E 06  CQR   0.763973E 06
                          CX    0.201345E 04   CH    0.139667E 05   CM    0.150003E 05   CD    0.150000E 05  CST   0.243101E 05
                         CSR    0.136205E 05   CA    0.970660E 06   CB    0.890853E 06

OPTIMUM SYSTEM COST BURDENS                   CTO    0.495381E 06  CRO    0.743228E 05  CQO    0.563973E 06  CGO   0.743228E 05
                          CV    0.120800E 07   CS    0.259144E 07

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INFORMATION RATE,RB     0.10000E 03
OPTIMUM SYSTEM PARAMETERS              DTO     0.504820E 00  DRO    0.873472E 02  PTO    0.856984E 01  THERO    0.1000E-02

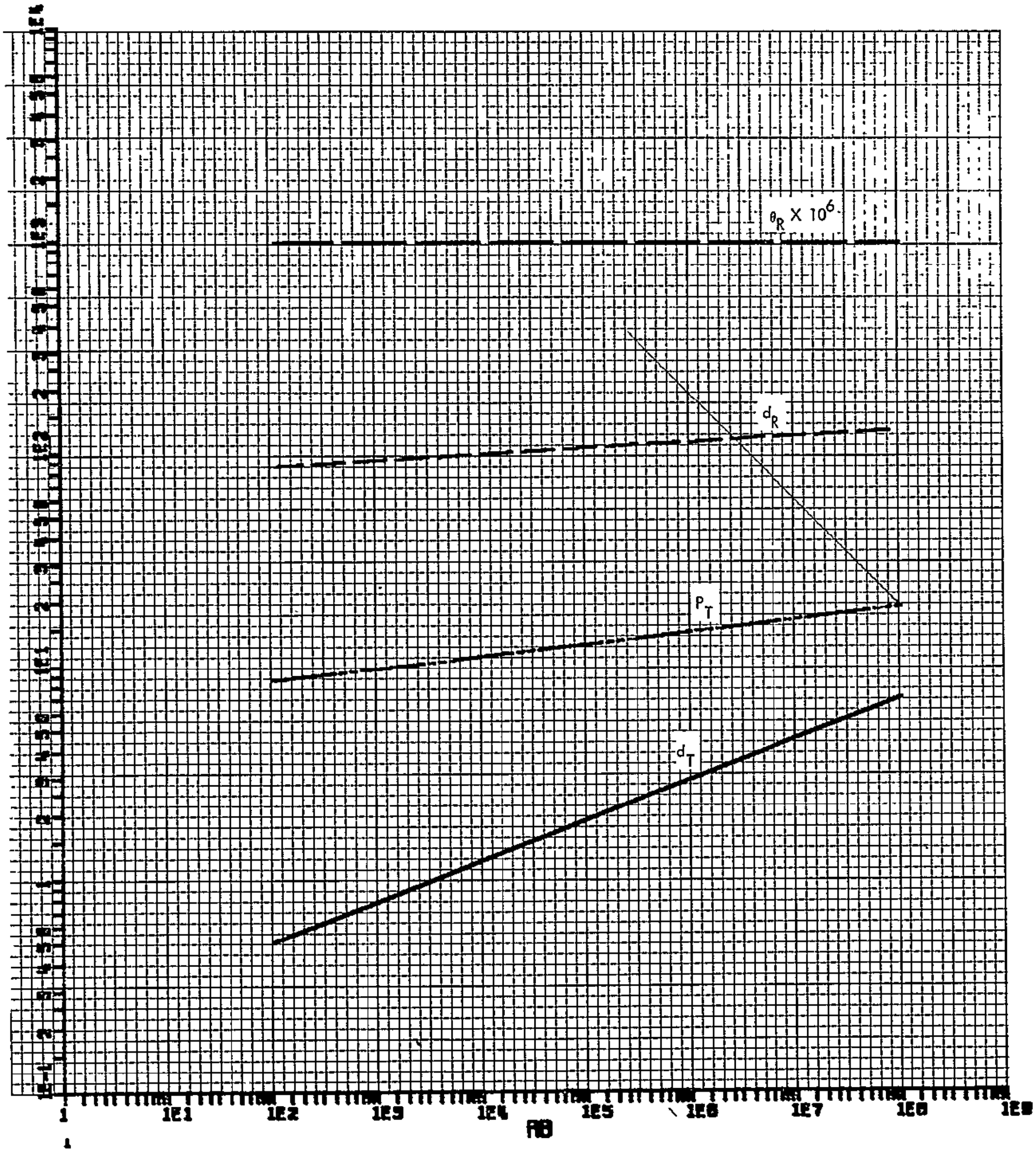
OPTIMUM WEIGHT BURDENS  WDT     0.250025E 02  WDR     0.195479E 03  WQT     0.500117E 01  WQR     0.857205E 02   WX     0.421397E 02
                         WH     0.192821E 01   WM     0.100000E 02   WD     0.300000E 02  WST     0.216816E 02  WSR     0.
                         WA     0.105753E 03   WB     0.311200E 03

OPTIMUM POWER BURDENS   PQT     0.240056E 01  PQR     0.411458E 02   PX     0.856984E 02   PM     0.500001E 02   PD     0.999000E 02
                         PA     0.138099E 03   PB     0.141046E 03

OPTIMUM FABRICATION COST BURDENS              CDT     0.200036E 05  CDR     0.917585E 05  CQT     0.851448E 06  CQR     0.763973E 06
                         CX     0.201225E 04   CH     0.139519E 05   CM     0.150000E 05   CD     0.150000E 05  CST     0.229245E 05
                        CSR     0.135261E 05   CA     0.925340E 06   CB     0.884258E 06

OPTIMUM SYSTEM COST BURDENS                   CTO     0.451458E 06  CRO     0.677271E 05  CQO     0.563973E 06  CGO     0.677271E 05
                         CV     0.115089E 07   CS     0.249340E 07

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```


$\theta_R \times 10^6$
d_R
P_T
d_T
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9
RB

Example B: Mars Spacecraft Transmitter to Earth Receiver Link

0.51 micron wavelength

PCM polarization modulation

Shot Noise Limited Operation

Transmitter system weight and fabrication cost, and receiver fabrication cost jointly optimized.

Parameters to be optimized:

a. Transmitter antenna diameter

b. Receiver antenna diameter

c. Transmitter power

d. Receiver field of view

Fixed Parameters: None

Parameter Stops:

a. Transmitter antenna diameter at 50 cm

b. Receiver field of view at 2.5 microradians

NAME ________________ DATE __________ PROBLEM EXAMPLE B

COPTRAN INSTRUCTIONS AND DATA

INSTRUCTION TYPE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	1	S	P	X	M	T	R																			SPACECRAFT TRANSMITTER
2	2	E	A	R	C	V	R																			EARTH RECEIVER
3	3	R	A	N	M	A	R																			MARS RANGE
4	4	L	A	M	0	5	1																			0.51 MICRON TRANSMISSION WAVELENGTH
5	5	B	K	D	S	K	Y																			DAY SKY BACKGROUND
6	6	P	C	M	/	P	L																			PCM POLARIZATION MODULATION
6	7	O	P	T	D	I	R																			OPTICAL DIRECT DETECTION
7	8	X	M	W	T	O	P																			TRANSMITTER SYSTEM WEIGHT & FABRICATION
7	9	X	M	F	C	O	P																			COST AND RECEIVER SYSTEM FABRICATION
7	10	R	C	F	C	O	P																			COST JOINTLY OPTIMIZED
8	11	D	T	D	R	O	P																			TRANSMITTER & RECEIVER ANTENNA DIAMETEROPT.
10	12	R	B	F	R	Q	O																			DATA POINTS AT RB = 10°, 0.2 x 10',
10	13	R	B	I	N	T	O																			0.3 x 10', . . . , 10^8 BITS PER SECOND
10	14	R	B	F	I	N	8																			
11	15	P	R	T	D	A	T																			PRINT OUT ALL SYSTEM DATA
12	16	P	L	T	O	P	T																			PLOT VALUES OF OPT. SYSTEM PARAMETERS
13	17	E	N	D	I	N	S																			END OF COPTRAN INSTRUCTIONS
DATA	18	T	H	E	R	B								2	•	5			E	-	6					2.5 RAD STOPS ON RECEIVING FIELD OF VIEW
DATA	19	D	T	B									5	0	•											50 CM STOP ON TRANSMITTER ANT. DIAM.
DATA	20	D	T	I									4	5	•											INITIAL VALUE OF TRANSMITTER ANT. DIAM.
14	21	E	N	D	D	A	T																			END OF COPTRAN DATA DECK
15	22	E	N	D	C	A	S																			END OF COPTRAN CASES
	23																									
	24																									
	25																									

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 0.51 MICRONS
DAY SKY BACKGROUND
PCM POLARIZATION MODULATION
OPTICAL DIRECT DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
RECEIVER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA DIAMETER AND RECEIVER ANTENNA DIAMETER OPTIMIZATION

*** COPTRAN PROGRAM **

SPXMTR
EARCVR
RANMAR
LAM051
BKDSKY
PCM/PL
OPRDIR
XMWTOP
XMFCOP
RCFCOP

DTDROP
RBFRQO
RBINTO
RBFIN8
PRTDAT
PLTOPT
ENDINS
THERR        2.5  E.06
DTB         50.
DTI         45.
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	KTHT	14.00000	KDT	0.01000	CKT	20000.00	WKT	25.00	MT	2.00	NT	2.00000
RECEIVER ANTENNA	KTHR	8.75000	KDR	0.0230000	CKR	25000.00	WKR	20.00000	MR	2.00000	NR	2.00000
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.46000	KPQT	0.48000	CAT	400000.	WBT	5.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	71000.	KWAR	0.46000	KPQR	0.48000	CAR	200000.	WBR	5.000	QR	0.30000
TRANSMITTER	KPT	150.00000	KWT	51.00000	KH	0.58000	KX	0.00700	KE	0.00100	CKP	3500.00
	CKH	13800.	WKP	40.000	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.00007	KM	0.00000	KPM	5.00000	CKM	7500.	WKM	5.00		
DEMODULATION EQUIPMENT	KFD	0.0000550	KD	0.00000011	KPD	3.33000	CKD	15000.	WKD	30.000		
TRANSMITTER POWER SUPPLY	KST	112.000	KWST	0.110000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

```
                                        SYSTEM PHYSICAL DATA

 R        0.10000E 14  LAMBDA  0.51000E-04  S/N     0.12000E 02  C/N     0.30000E 01  USBREQ  0.15000E 02  TAU-T   0.80000E 00
 TAU-R    0.70000E 00  TAU-A   0.80000E 00  TE      0.           ETA     0.20000E 00  RL      0.10000E 03  LMBD-I  0.10000E-02
 QB       0.20000E 17  RHO-I   0.98000E 00  RHO-R   0.98000E 00
******************************************************************************************************************************
******************************************************************************************************************************

                                   SIGNAL-TO-NOISE RATIO CONSTANTS

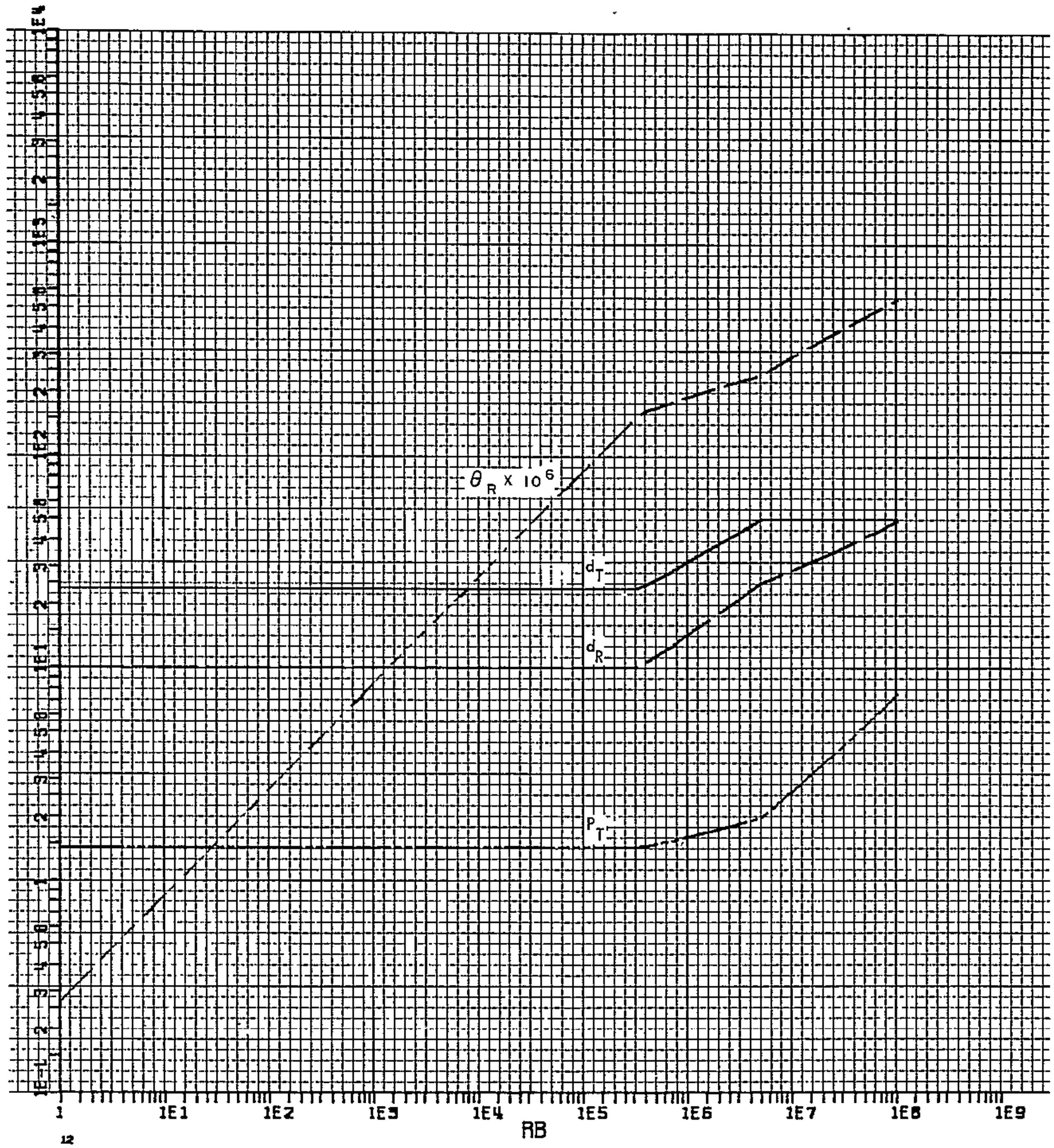
    K     0.26052E 13    KN     0.              KM    0.             KR    0.               KS     0.17679E-01
******************************************************************************************************************************
******************************************************************************************************************************

                                        SYSTEM BURDEN CONSTANTS

    KMT   0.14000E 02    KNT    0.24590E 02     KQT   0.13772E 07 KMR        0.87500E 01    KNR    0.12696E 00     KQR   0.71000E 05
    KGT   0.15000E 03    KHI    0.83640E 05     KJT   0.30445E 06
******************************************************************************************************************************
******************************************************************************************************************************

                                       PARAMETER CONSTRAINTS

 DTI      0.45000E 02  GTI     0.               DRI     0.50000E 03  GRI     0.               PTI     0.25000E 02  THERI   0.20000E-04
 DTM      0.           GTM     0.               DRM     0.           GRM     0.               PTM     0.           THERM   0.
 DTB      0.50000E 02  GTB     0.               DRB     0.10000E 04  GRB     0.               PTB     0.50000E 02  THERB   0.10000E-04
******************************************************************************************************************************
```



$\theta_R \times 10^6$
d_T
d_R
P_T
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9
RB

Example C: Jupiter Spacecraft Transmitter to Earth Receiver Link

10.6 micron wavelength

PCM frequency shift keying

Shot noise limited operation

Transmitter system weight optimization

Parameters to be optimized:

a. Transmitter antenna diameter

b. Receiver antenna diameter

c. Transmitter power

Fixed Parameters

a. Receiver field of view at 1 milliradian

Parameter Stops

a. Transmitter power at 1 kw

b. Receiver antenna diameter at 1 meter

c. Receiver antenna diameter at 50 cm

NAME ____________ DATE ____________ PROBLEM EXAMPLE C

COPTRAN INSTRUCTIONS AND DATA

INSTRUCTION TYPE*		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	1	S	P	X	M	T	R																			SPACECRAFT TRANSMITTER
2	2	E	A	R	C	V	R																			EARTH RECEIVER
3.	3	R	A	N	J	U	P																			JUPITER RANGE
4	4	L	A	M	1	0	6																			10.6 MICRON TRANSMISSION WAVELENGTH
5	5	B	K	D	S	K	Y																			DAY SKY BACKGROUND
6	6	P	C	M	/	F	M																			PCM FREQUENCY SHIFT KEYING
6	7	O	P	T	H	E	T																			OPTICAL HETERODYNE DETECTION
7	8	X	M	W	T	O	P																			TRANSMITTER SYSTEM WEIGHT OPTIMIZATION
8	9	D	T	D	R	O	P																			TRANSMITTER & RECEIVER ANTENNA WT. OPT.
10	10	R	B	F	R	Q	0																			DATA POINTS AT RB = 10^{0}, 0.2×10^{1}, 0.3×10^{1}, . . . , 10^{7} BPS
10	11	R	B	I	N	T	0																			
10	12	R	B	F	I	N	7																			
11	13	P	R	T	D	A	T																			PRINT SYSTEM DATA & CONSTANTS
12	14	P	L	T	O	P	T																			PLOT VALUES OF OPTIMUM SYSTEM PARAMETERS
13	15	E	N	D	I	N	S																			END OF COPTRAN INSTRUCTIONS
DATA	16	P	T	B										1	•	0				E	+	0	3			1 KW STOP ON XMTR POWER
DATA	17	D	R	M								1	0	0	•											1 METER STOP ON RECEIVER ANT. DIAMETER
DATA	18	D	T	B									5	0	•											50 CM STOP ON TRANSMITTER ANT. DIAMETER
DATA	19	T	H	E	R	M								1	•	0				E	–	0	3			1 MILLIRADIAN FIXED RECEIVER FIELD OF VIEW
14	20	E	N	D	D	A	T																			END OF COPTRAN DATA
REPEAT	21	R	E	P	E	A	T																			REPEAT PRECEDING CASE
13	22	E	N	D	I	N	S																			END OF COPTRAN INSTRUCTIONS
DATA	23	D	T	B									8	0	•											NEW XMTR ANT. DIAM. STOP = 80 CM
14	24	E	N	D	D	A	T																			END OF DATA
15	25	E	N	D	C	A	S																			END OF CASES

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
JUPITER RANGE(7.8E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 10.6 MICRONS
DAY-SKY BACKGROUND
PCM FREQUENCY MODULATION
OPTICAL HETERODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER ANTENNA DIAMETER AND RECEIVER ANTENNA DIAMETER OPTIMIZATION

*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
RANJUP
CAM106
BKDSKY
PCM/FM
OPTHET
XMWTOP
DTDROP
RBFRO0
RBINTO
RBFIN7

PRTDAT
PLTOUT
ENDINS
PTB          1.0   E+03
DRM        100.
DTB          50.
THERM        1.0   E-03
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	KTHT	14.00000	KDT	0.01000	CKT	20000.00	WKT	25.00	MT	2.00	NT	2.00000
RECEIVER ANTENNA	KTHR	8.75000	KDR	0.0230000	CKR	25000.00	WKR	20.00000	MR	2.00000	NR	2.00000
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.46000	KPDT	0.48000	CAT	400000.	WBT	5.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	71000.	KWAR	0.46000	KPOR	0.48000	CAR	200000.	WBR	5.000	QR	0.30000
TRANSMITTER	KPT	1.43000	KWT	2.00000	KH	1.97000	KX	0.02500	KE	0.10000	CKP	2000.00
	CKH	13800.	WKP	25.000	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.00050	KM	0.00000	KPM	5.00000	CKM	15000.	WKM	10.00		
DEMODULATION EQUIPMENT	KFD	0.0001000	KD	0.00000020	KPD	3.33000	CKD	27500.	WKD	55.000		
TRANSMITTER POWER SUPPLY	KST	500.000	KWST	0.625000	CKE	1200000.	WKE	400.000				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

SYSTEM PHYSICAL DATA

R	0.75000E 14	LAMBDA	0.10600E-02	S/N	0.15000E 02	C/N	0.	USBREQ	0.	TAU-T	0.80000E 00
TAU-R	0.60000E 00	TAU-A	0.80000E 00	TE	0.	ETA	0.50000E 00	RL	0.10000E 03	LMBD-I	0.10000E-02
QB	0.	RHO-T	0.98000E 00	RHO-R	0.98000E 00						

****

****

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.16202E-04	KM	0.	KR	0.	KS	0.

****

****

SYSTEM BURDEN CONSTANTS

KMT	0.	KNT	0.26207E 02	KQT	0.	KMR	0.	KNR	0.	KQR	0.
KGT	0.	KHT	0.32800E 04	KJT	0.10619E 05						

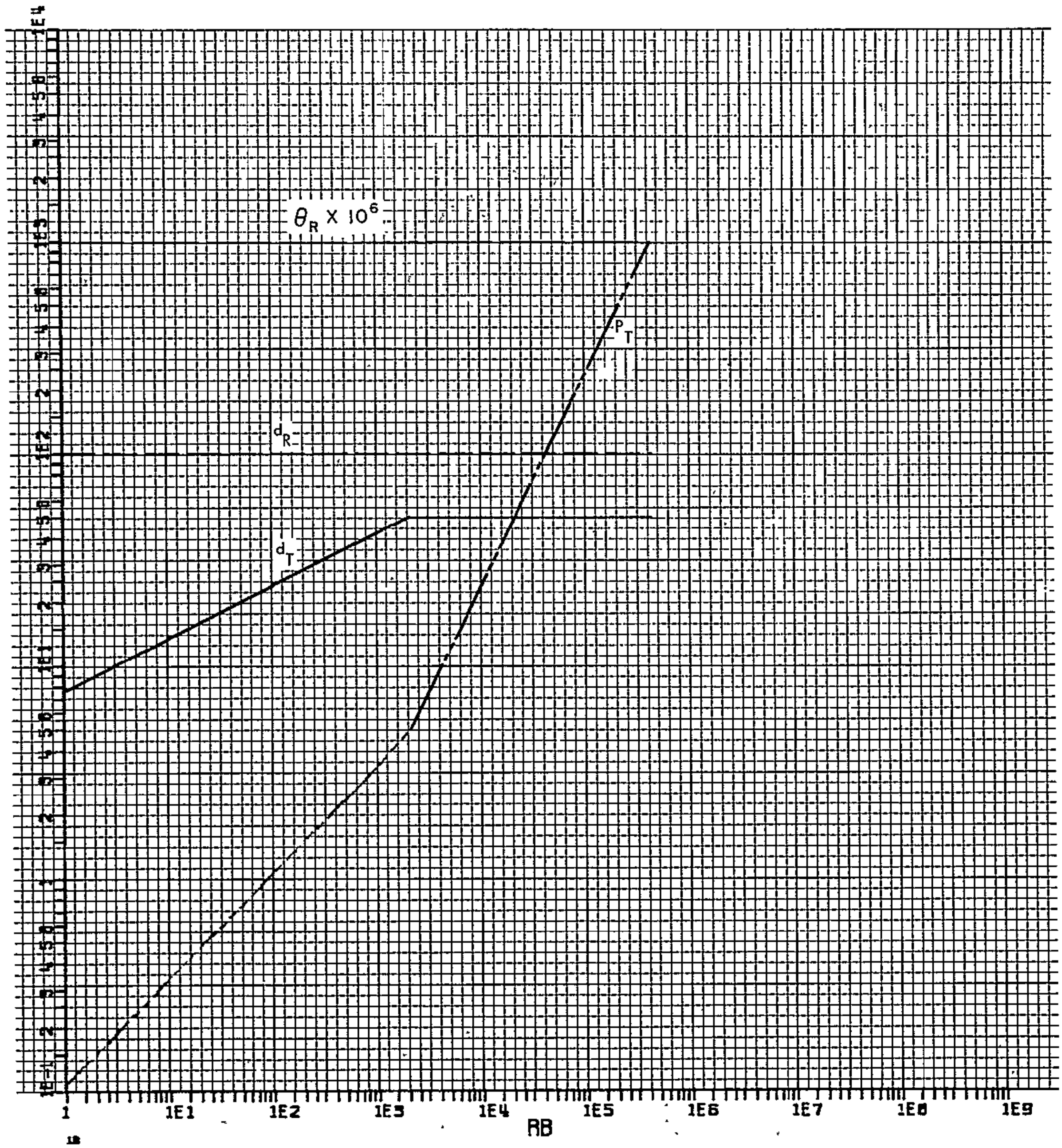
****

****

PARAMETER CONSTRAINTS

DTI	0.50000E 02	GTI	0.	DRI	0.10000E 03	GRI	0.	PTI	0.25000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.10000E 03	GRM	0.	PTM	0.	THERM	0.10000E-02
DTB	0.80000E 02	GTB	0.	DRB	0.10000E 03	GRB	0.	PTB	0.50000E 03	THERB	0.10000E-02

****


$\theta_R \times 10^6$
P_T
d_R
d_T
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9
RB

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
JUPITER RANGE(7.5E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 10.6 MICRONS
DAY SKY BACKGROUND
PCM-FREQUENCY MODULATION
OPTICAL HETERODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER ANTENNA DIAMETER AND RECEIVER ANTENNA DIAMETER OPTIMIZATION


*** CORTRAN PROGRAM ***

SPXMTR
EARCVR
RANJUP
LAM106
BKDSKY
PCM/FM
OPTHET
XMWTOP
DTDROP
RBFRQ0
RBINT0
RBFIN7

PRTDAT
PLTDAT
ENDINS
PTB          1.0   E+03
DRM        100.
DTB         50.
THERM        1.0   E-03
ENDDAT
REPEAT
ENDINS
DTB         80.
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	KTHT	14.00000	KDT	0.01000	CKT	20000.00	WKT	25.00	MT	2.00	NT	2.00000
RECEIVER ANTENNA	KTHR	8.75000	KDR	0.0230000	CKR	25000.00	WKR	20.00000	MR	2.00000	NR	2.00000
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.46000	KPQT	0.48000	CAT	400000.	WBT	5.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	71000.	KWAR	0.46000	KPQR	0.48000	CAR	200000.	WBR	5.000	QR	0.30000
TRANSMITTER	KPT	1.43000	KWT	2.00000	KH	1.97000	KX	0.02500	KE	0.10000	CKP	2000.00
	CKH	13800.	WKP	25.000	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.00050	KM	0.00000	KPM	5.00000	CKM	15000.	WKM	10.00		
DEMODULATION EQUIPMENT	KFD	0.0001000	KD	0.00000020	KPD	3.33000	CKD	27500.	WKD	55.000		
TRANSMITTER POWER SUPPLY	KST	500.000	KWST	0.625000	CKE	1200000.	WKE	400.000				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.75000E 14	LAMBDA	0.10600E-02	S/N	0.15000E 02	C/N	0.	USBREQ	0.	TAU-T	0.80000E 00
TAU-R	0.60000E 00	TAU-A	0.80000E 00	TE	0.	ETA	0.50000E 00	RL	0.10000E 03	LMBD-I	0.10000E-02
QB	0.	RHO-T	0.98000E 00	RHO-R	0.98000E 00						

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.16202E-04	KM	0.	KR	0.	KS	0.

SYSTEM BURDEN CONSTANTS

KMT	0.	KNT	0.26207E 02	KQT	0.	KMR	0.	KNR	0.	KQR	0.
KGT	0.	KHT	0.32800E 04	KJT	0.10619E 05						

PARAMETER CONSTRAINTS

DTI	0.50000E 02	GTI	0.	DRI	0.10000E 03	GRI	0.	PTI	0.25000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.10000E 03	GRM	0.	PTM	0.	THERM	0.10000E-02
DTB	0.50000E 02	GTB	0.	DRB	0.10000E 03	GRB	0.	PTB	0.10000E 04	THERB	0.10000E-02


$\theta_R \times 10^6$
d_R
P_T
d_T
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9
RB

Example D: Mars Spacecraft Transmitter to Earth Receiver Link

13 cm wavelength

PCM phase shift keying

Thermal noise limited operation

Transmitter system weight and fabrication cost jointly optimized

Parameters to be optimized:

a. Transmitter antenna diameter

b. Transmitter power

Fixed Parameters:

a. Receiver antenna diameter at 64 meters

b. Receiver field of view of 1 milliradian

Parameter stops

a. Transmitter power at 1 kw

Data values:

a. Transmitter antenna efficiency = 60%

b. Revised transmitter burdens (1980 estimates)

NAME __________ DATE __________ PROBLEM EXAMPLE. D

COPTRAN INSTRUCTIONS AND DATA

INSTRUCTION TYPE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	1	S	P	X	M	T	R																			SPACECRAFT TRANSMITTER
2	2	E	A	R	C	V	R																			EARTH RECEIVER
3	3	R	A	N	M	A	R																			MARS RANGE
4	4	L	A	M	1	3	C																			13 CM TRANSMISSION WAVELENGTH
5	5	B	K	G	A	L	T																			GALACTIC BACKGROUND
6	6	P	C	M	/	P	M																			PCM PHASE SHIFT KEYING
6	7	R	A	D	H	O	M																			COHERENT RADIO HOMODYNE DETECTION
7	8	X	M	W	T	O	P																			XMTR SYSTEM WEIGHT AND XMTR SYSTEM
7	9	X	M	F	C	O	P																			FABRICATION COST JOINTLY OPTIMIZED
8	10	G	T	G	R	O	P																			TRANSMITTER & RECEIVER ANT GAIN OPTIMIZATION
9	11	N	X	P	W	S	A																			RTG XMTR POWER SUPPLY BURDENS
10	12	R	B	F	R	Q	0																			DATA POINTS AT $R_B = 10^0$, 0.2×10^1, 0.3×10^1,
10	13	R	B	I	N	T	0																			. . . , 10^7 BITS PER SECOND
10	14	R	B	F	I	N	7																			
11	15	P	R	T	D	A	T																			PRINT SYSTEM DATA AND CONSTANTS
12	16	P	L	T	O	P	T																			PLOT OPTIMUM SYSTEM PARAMETERS
12	17	P	L	T	C	S																				TOTAL COST, AND TRANSMITTER
12	18	P	L	T	W	A																				OPTIMUM WEIGHT
13	19	E	N	D	I	N	S																			END OF COPTRAN INSTRUCTIONS
	20																									
DATA	21	R	H	O	T										•	6	0									TRANSMITTER ANTENNA EFFICIENCY
DATA	22	K	P	T									9	6	•											
DATA	23	K	W	T											•	0	8									REVISED TRANSMITTER BURDENS
DATA	24	K	H												•	4	6									
DATA	25	K	X											5	•	6				E	–	0	3			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	

*See TABLE IV-I

NAME ______________ DATE __________ PROBLEM EXAMPLE D (continued)

COPTRAN INSTRUCTIONS AND DATA

INSTRUCTION TYPE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
DATA	1	K	E												•	2	5									
DATA	2	C	X											8	•	7	5	0		E	+	0	3			
DATA	3	C	H											6	•	8	7	5		E	+	0	3			
DATA	4	W	K	P										2	•	5										REVISED TRANSMITTER BURDENS
DATA	5	W	K	H											•	0										
DATA	6	G	T											1	•											
DATA	7	H	T											1	•											
DATA	8	J	T											1	•											
DATA	9	G	R	M										1	•	9				E	+	0	6			GAIN FOR 64 METER FIXED RECEIVER ANT. DIAM.
DATA	10	P	T	B										1	•					E	+	0	3			1 KW STOP ON XMTR POWER
DATA	11	T	H	E	R	M								1	•					E	−	0	3			1 MILLIRADIAN FIXED RECEIVER FIELD ON VIEW
INCREMENT	12	N	C	R	M	N	T						1	5	•											INCREMENT SN FROM 20 TO 50
SET	13	S	N										2	0	•											IN STEP SIZES OF 15
	14	F	I	N	A	L	E						5	0	•											
14	15	E	N	D	D	A	T																			END OF COPTRAN DATA
15	16	E	N	D	C	A	S																			END OF CASES
	17																									
	18																									
	19																									
	20																									
	21																									
	22																									
	23																									
	24																									
	25																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	

*See TABLE IV-I

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 13 CM
GALACTIC BACKGROUND
PCM PHASE MODULATION
RADIO HOMODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA GAIN AND RECEIVER ANTENNA GAIN OPTIMIZATION


*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
RANMAR
LAM13C
BKGALT
PCM/PM
RADHOM
XMWTOP
XMFCOP
GTGROP
NXPWSA
RBFRQO
RBINTO
RBFIN7
PRTDAT
PLTOPT
PLTCS
PLTWA
ENDINS
RHOT          0.600
KPT           96.0
KWT      0.800E-01
KH            0.460
KX       0.560E-02
KE            0.250
CX       0.875E 04
CH       0.688E 04
WKP           2.50
WKH      0.
GT            1.00
HT            1.00
JT            1.00
GRM      0.190E 07
PTB      0.100E 04
THERM    0.100E-02
NCRMNT        15.0
SN            20.0
FINALE        50.0
ENDDAT   0.
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	HTHT	520.00000	HDT	0.01350	CKT	5000.00	WKT	0.	MT	1.00	NT	1.00000
RECEIVER ANTENNA	HTHR	0.06600	HDR	0.	CKR	0.	WKR	0.	MR	1.35	NR	0.
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.75000	KPOT	10.00000	CAT	140000.	WBT	10.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	0.	KWAR	0.	KPOR	0.	CAR	0.	WBR	0.	QR	0.
TRANSMITTER	KPT	96.00000	KWT	0.08000	KH	0.46000	KX	0.00560	KE	0.25000	CKP	17500.00
	CKH	23800.	WKP	2.500	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.	KM	0.	KPM	0.	CKM	0.	WKM	0.		
DEMODULATION EQUIPMENT	KFD	0.	KD	0.	KPD	0.	CKD	0.	WKD	0.		
TRANSMITTER POWER SUPPLY	KST	3000.000	KWST	0.700000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.10000E 14	LAMBDA	0.13000E 02	S/N	0.20000E 02	C/N	0.	USAREQ	0.	TAU-T	0.75000E 00
TAU-R	0.35000E 00	TAU-A	0.95000E 00	TE	0.27000E 02	ETA	0.	RL	0.	LMBD-I	0.
QB	0.	RHO-T	0.60000E 00	RHO-R	0.80000E 00						

****

****

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.	KM	0.	KR	0.89534E-07	KS	0.

****

****

SYSTEM BURDEN CONSTANTS

KMT	0.	KNT	0.	KQT	0.71000E 05	KMR	0.	KNR	0.	KQR	0.
KGT	0.96000E 02	KHT	0.13120E 03	KJT	0.16621E 05						

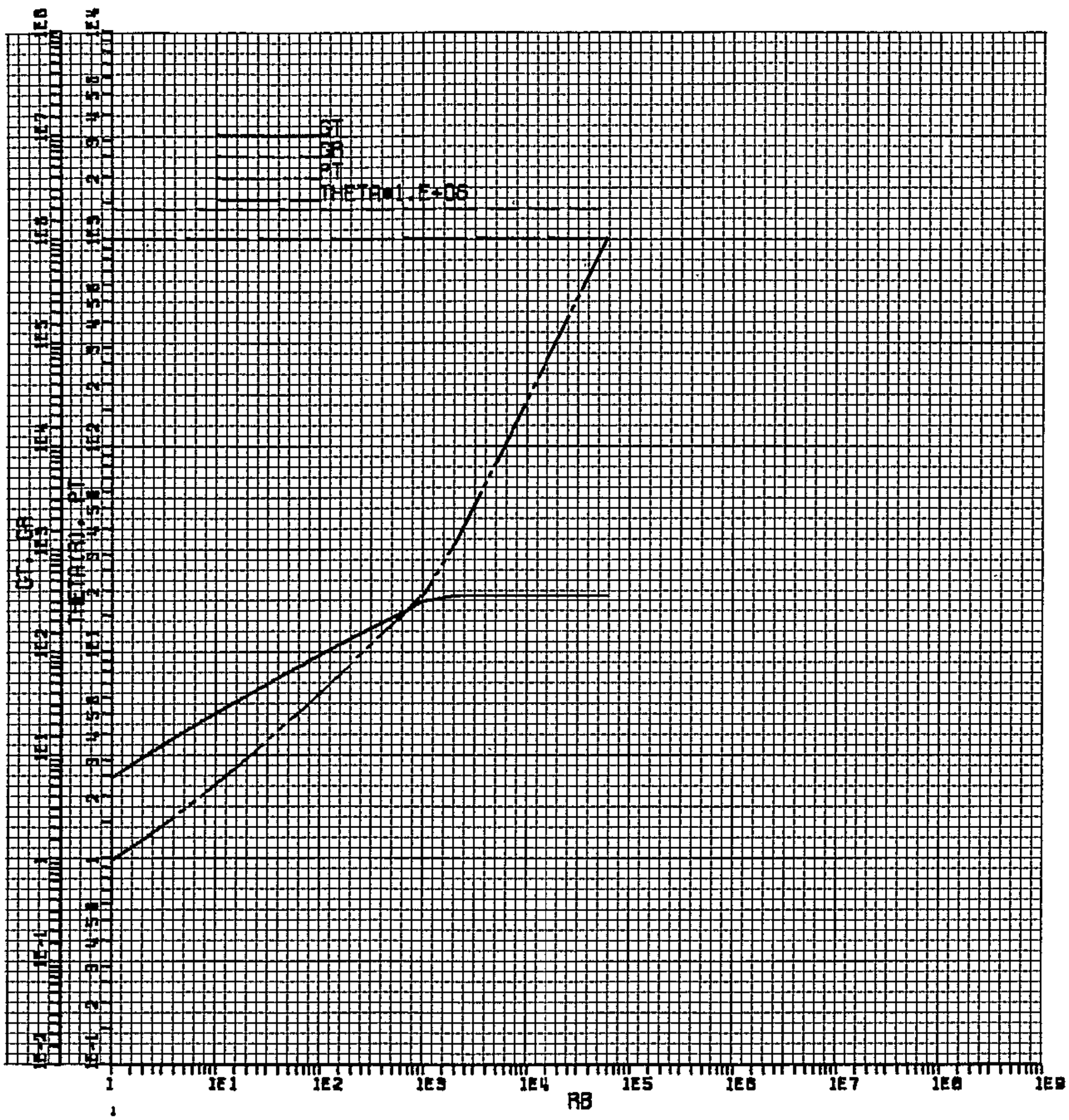
****

****

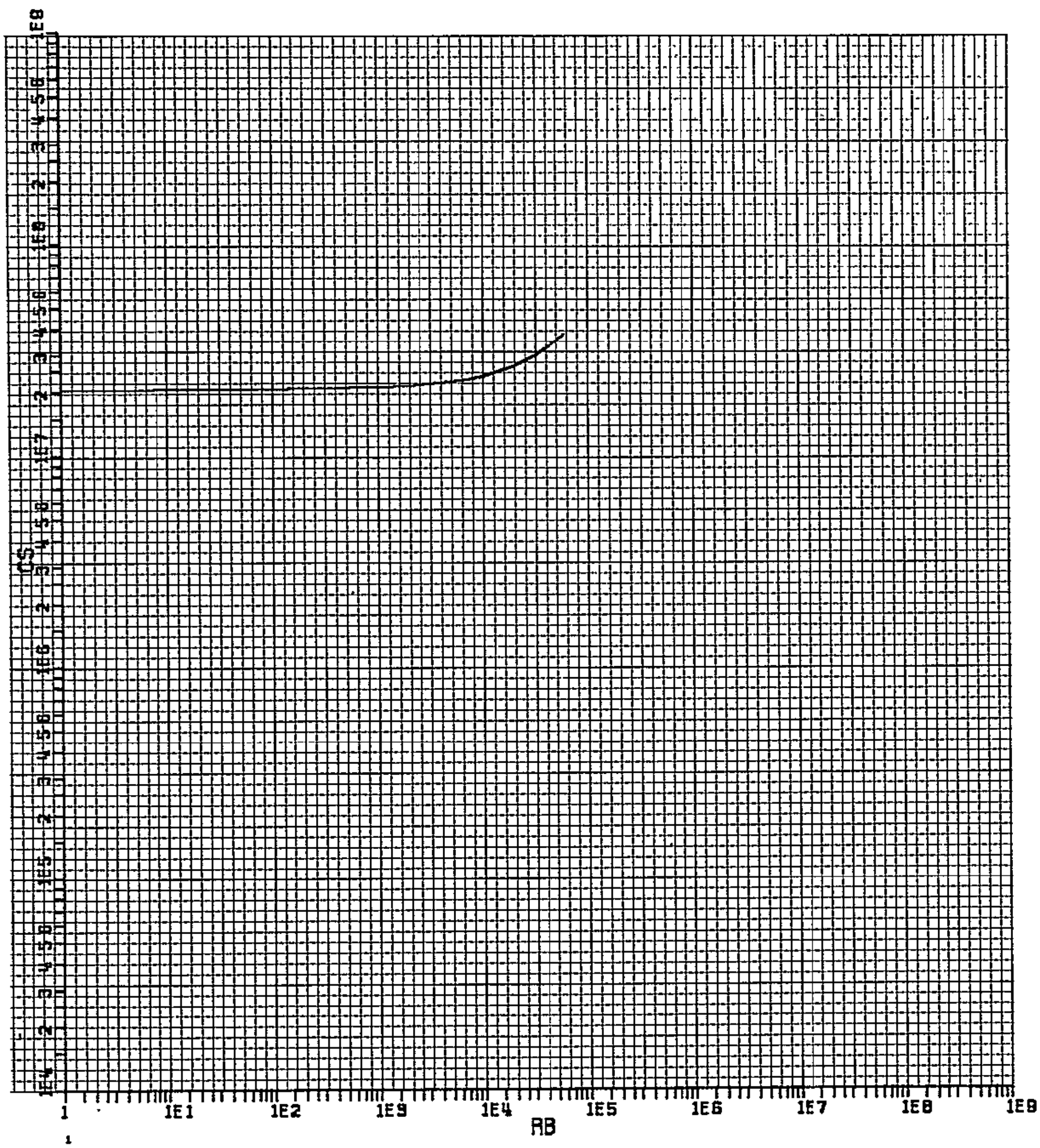
PARAMETER CONSTRAINTS

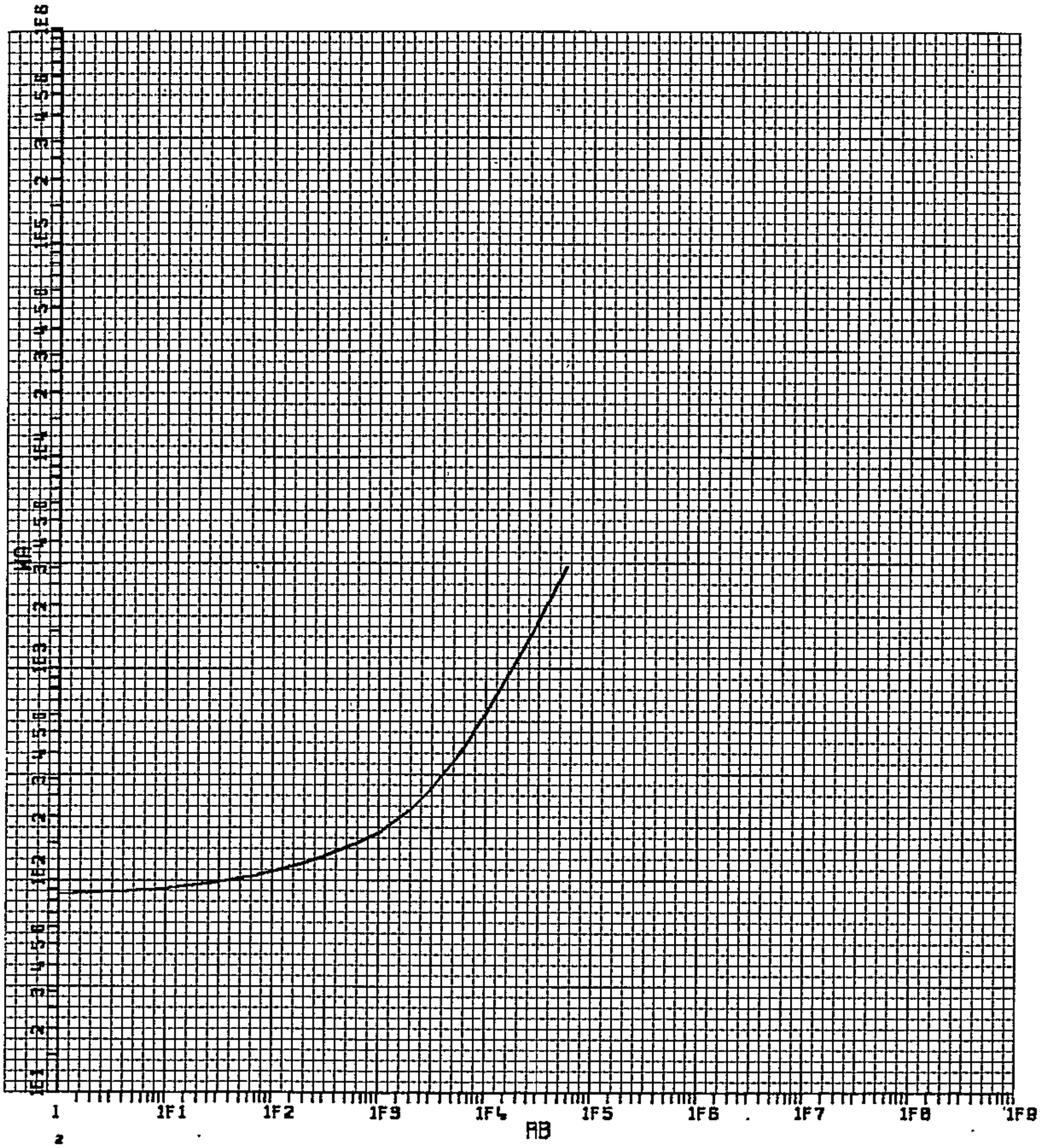
DTI	0.	GTI	0.17400E 03	DRI	0.	GRI	0.19000E 07	PTI	0.50000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.19000E 07	PTM	0.	THERM	0.10000E-02
DTB	0.	GTB	0.34800E 03	DRB	0.	GRB	0.19000E 07	PTB	0.10000E 04	THERB	0.10000E-02

****



CT
CR
PT
THETA=1.E+06
CT, CR
THETA(RI), PT
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9


CS
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9



1E8
4 5 8
3
2
1E5
4 5 8
3
2
1E4
4 5 8
3
2
1E3
4 5 8
3
2
1E2
4 5 8
3
2
1E1
WA
1
1F1
1F2
1F3
1F4
1F5
1F6
1F7
1F8
1F9
AB

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 13 CM
GALACTIC BACKGROUND
PCM PHASE MODULATION
RADIO HOMODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA GAIN AND RECEIVER ANTENNA GAIN OPTIMIZATION


*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
RANMAR
LAM13C
BKGALT
PCM/PM
RADHOM
XMWTOP
XMFCOP
GTGROP
NXPWSA
RBFRQ0
RBINT0
RBFIN7
PRTDAT
PLTOPT
PLTCS
PLTWA
ENDINS
RHOT              0.600
KPT                96.0
KWT           0.800E-01
KH                0.460
KX            0.560E-02
KE                0.250
CX            0.875E 04
CH            0.688E 04
WKP                2.50
WKH           0.
GT                 1.00
HT                 1.00
JT                 1.00
GRM           0.190E 07
PTB           0.100E 04
THERM         0.100E-02
NCRMNT             15.0
SN                 20.0
FINALE             50.0
ENDDAT        0.
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	HTHT	520.00000	HDT	0.01350	CKT	5000.00	WKT	0.	MT	1.00	NT	1.00000
RECEIVER ANTENNA	HTHR	0.06600	HDR	0.	CKR	0.	WKR	0.	MR	1.35	NR	0.
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.75000	KPQT	10.00000	CAT	140000.	WBT	10.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	0.	KWAR	0.	KPQR	0.	CAR	0.	WBR	0.	QR	0.
TRANSMITTER	KPT	96.00000	KWT	0.08000	KH	0.46000	KX	0.00560	KE	0.25000	CKP	17500.00
	CKH	23800.	WKP	2.500	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.	KM	0.	KPM	0.	CKM	0.	WKM	0.		
DEMODULATION EQUIPMENT	KFD	0.	KD	0.	KPD	0.	CKD	0.	WKD	0.		
TRANSMITTER POWER SUPPLY	KST	3000.000	KWST	0.700000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.10000E 14	LAMBDA	0.13000E 02	S/N	0.35000E 02	C/N	0.	USBREQ	0.	TAU-T	0.75000E 00		
TAU-R	0.35000E 00	TAU-A	0.95000E 00	TE	0.27000E 02	ETA	0.	RL	0.	LMBD-I	0.		
QB	0.	RHO-T	0.60000E 00	RHO-R	0.80000E 00								

****

****

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.	KM	0.	KR	0.51162E-07	KS	0.

****

****

SYSTEM BURDEN CONSTANTS

KMT	0.	KNT	0.	KQT	0.71000E 05	KMR	0.	KNR	0.	KQR	0.
KGT	0.96000E 02	KHT	0.13120E 03	KJT	0.16621E 05						

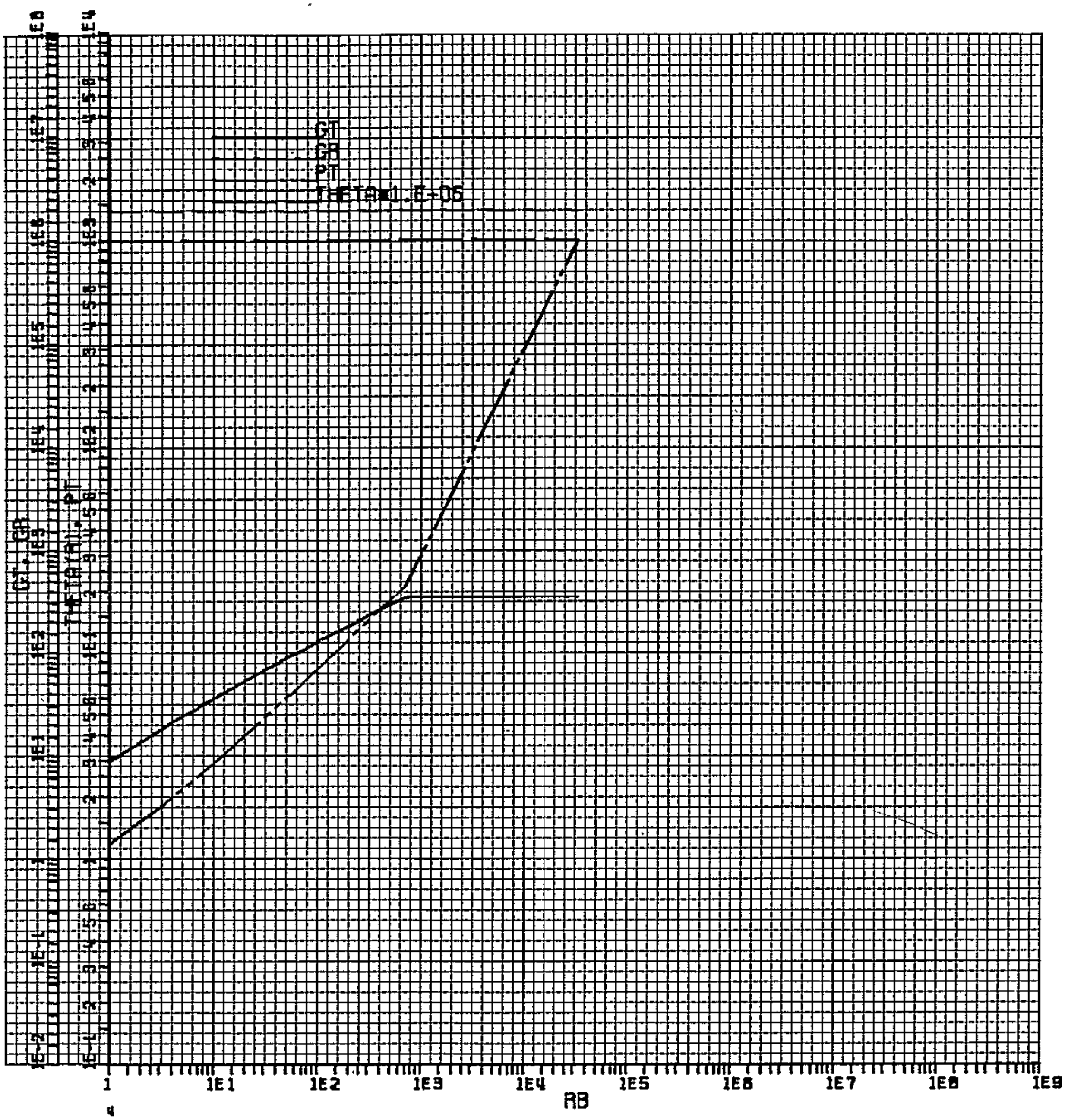
****

****

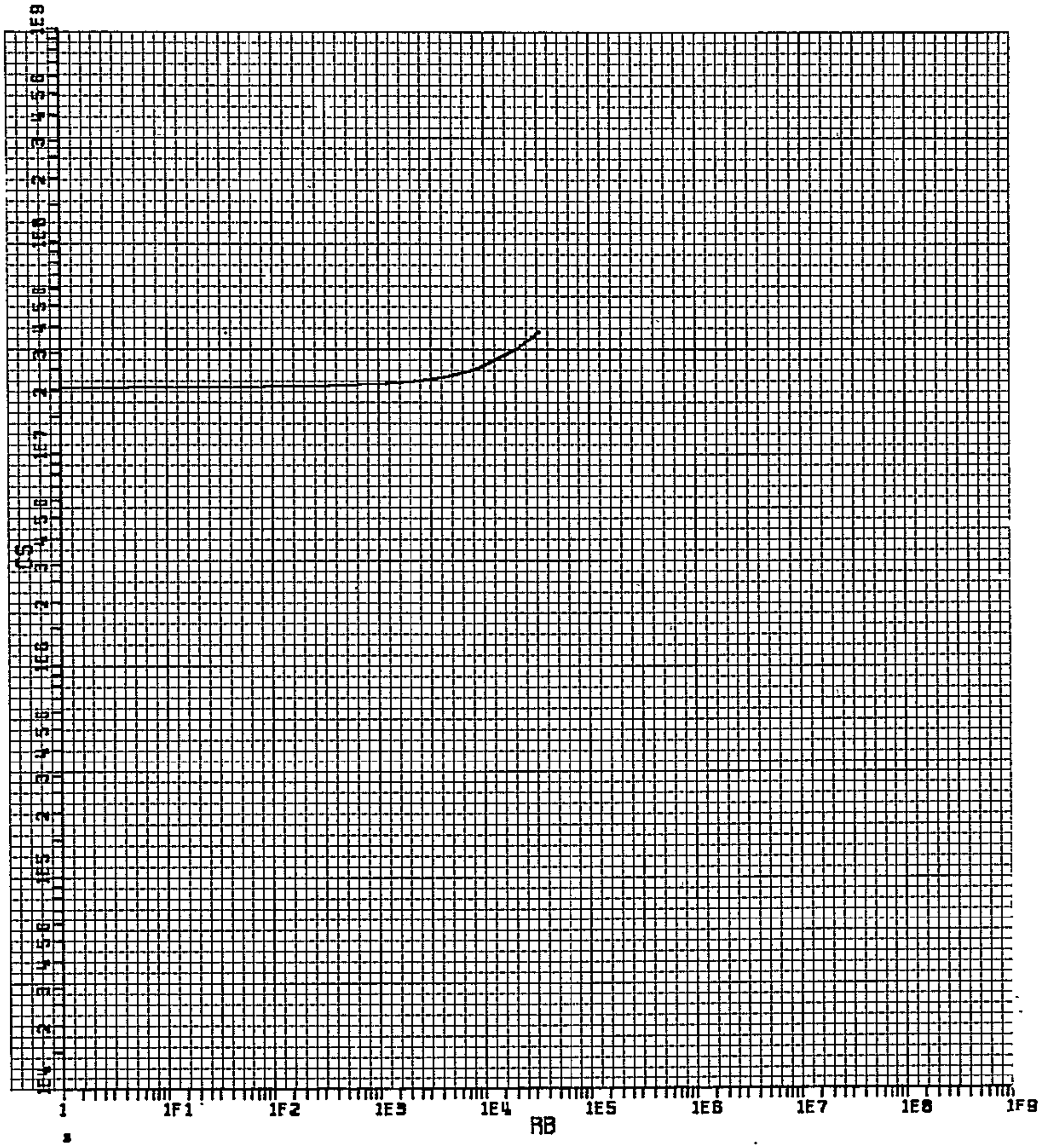
PARAMETER CONSTRAINTS

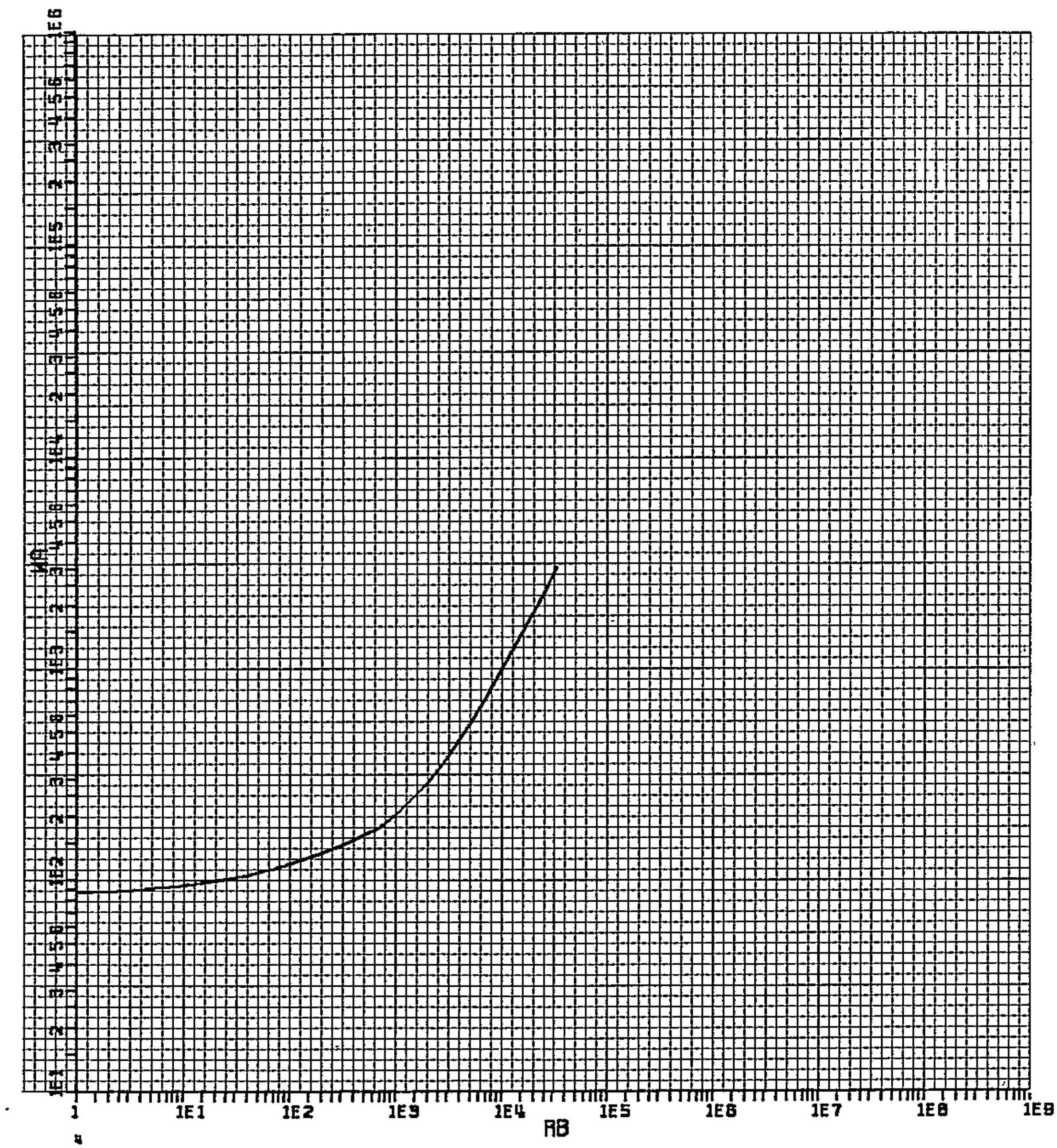
DTI	0.	GTI	0.17400E 03	DRI	0.	GRI	0.19000E 07	PTI	0.50000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.19000E 07	PTM	0.	THERM	0.10000E-02
DTB	0.	GTB	0.34800E 03	DRB	0.	GRB	0.19000E 07	PTB	0.10000E 04	THERB	0.10000E-02

****



GT
GB
PT
THETA=1.E+06
GT, GB
THETA(R1), PT
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9


QS
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9


KA
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 13 CM
GALACTIC BACKGROUND
PCM PHASE MODULATION
RADIO HOMODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA GAIN AND RECEIVER ANTENNA GAIN OPTIMIZATION


*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
RANMAR
LAM13C
BKGALT
PCM/PM
RADHOM
XMWTOP
XMFCOP
GTGROP
NXPWSA
RBFRQ0
RBINT0
RBFIN7
PRTDAT
PLTOPT
PLTCS
PLTWA
ENDINS
RHOT              0.600
KPT                96.0
KWT           0.800E-01
KH                0.460
KX            0.560E-02
KE                0.250
CX            0.875E 04
CH            0.688E 04
WKP                2.50
WKH           0.
GT                 1.00
HT                 1.00
JT                 1.00
GRM           0.190E 07
PTB           0.100E 04
THERM         0.100E-02
NCRMNT             15.0
SN                 20.0
FINALE             50.0
ENDDAT        0.
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	HTHT	520.00000	HDT	0.01350	CKT	5000.00	WKT	0.	MT	1.00	NT	1.00000
RECEIVER ANTENNA	HTHR	0.06600	HDR	0.	CKR	0.	WKR	0.	MR	1.35	NR	0.
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.75000	KPQT	10.00000	CAT	140000.	WBT	10.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	0.	KWAR	0.	KPQR	0.	CAR	0.	WBR	0.	QR	0.
TRANSMITTER	KPT	96.00000	KWT	0.08000	KH	0.46000	KX	0.00560	KE	0.25000	CKP	17500.00
	CKH	23800.	WKP	2.500	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.	KM	0.	KPM	0.	CKM	0.	WKM	0.		
DEMODULATION EQUIPMENT	KFD	0.	KD	0.	KPD	0.	CKD	0.	WKD	0.		
TRANSMITTER POWER SUPPLY	KST	3000.000	KWST	0.700000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.10000E 14	LAMBDA	0.13000E 02	S/N	0.50000E 02	C/N	0.	USBREQ	0.	TAU-T	0.75000E 00
TAU-R	0.35000E 00	TAU-A	0.95000E 00	TE	0.27000E 02	ETA	0.	RL	0.	LMBD-I	0.
QB	0.	RHO-T	0.60000E 00	RHO-R	0.80000E 00						

SIGNAL-TO-NOISE RATIO CONSTANTS

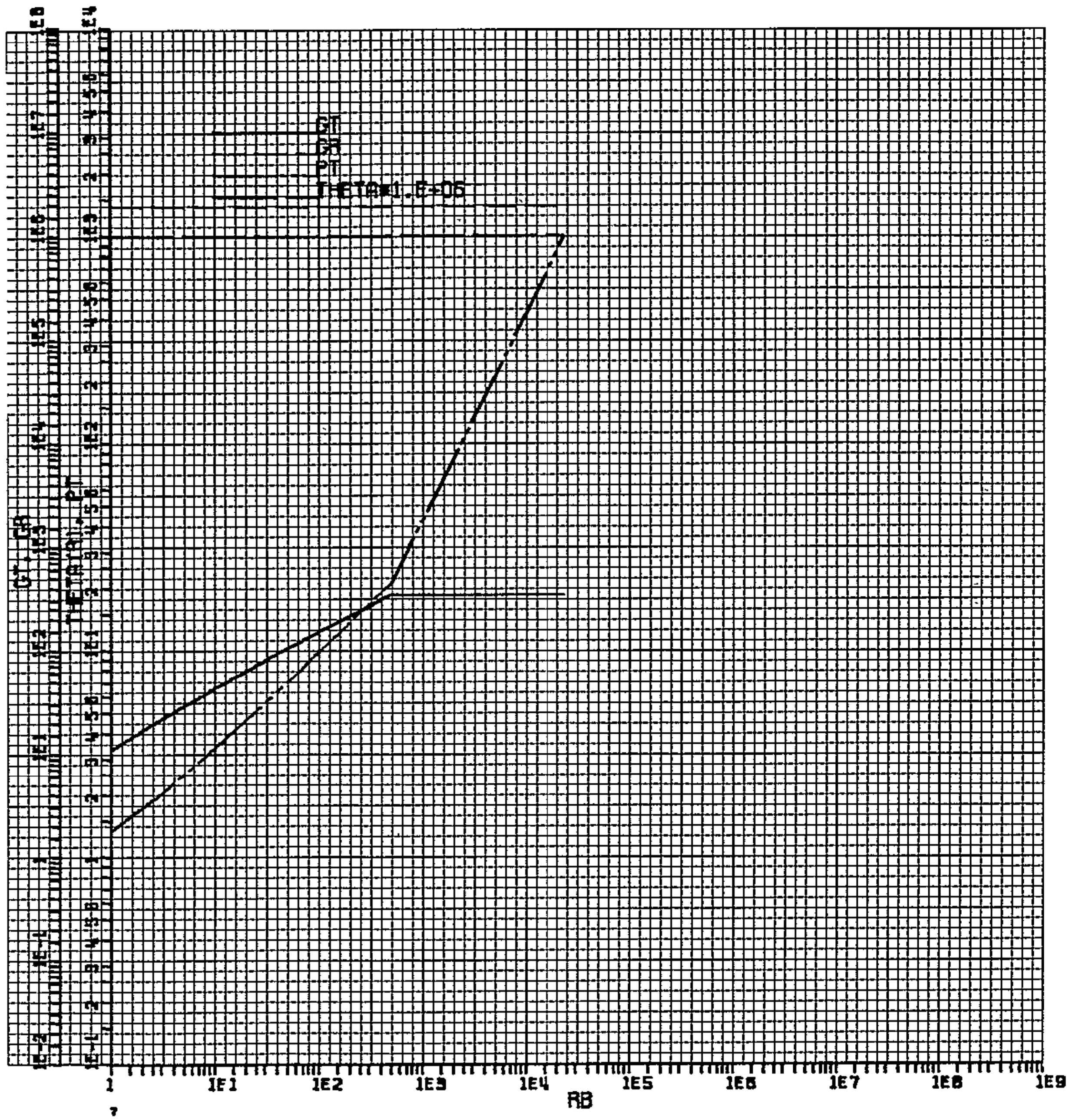
K	0.	KN	0.	KM	0.	KR	0.35814E-07	KS	0.

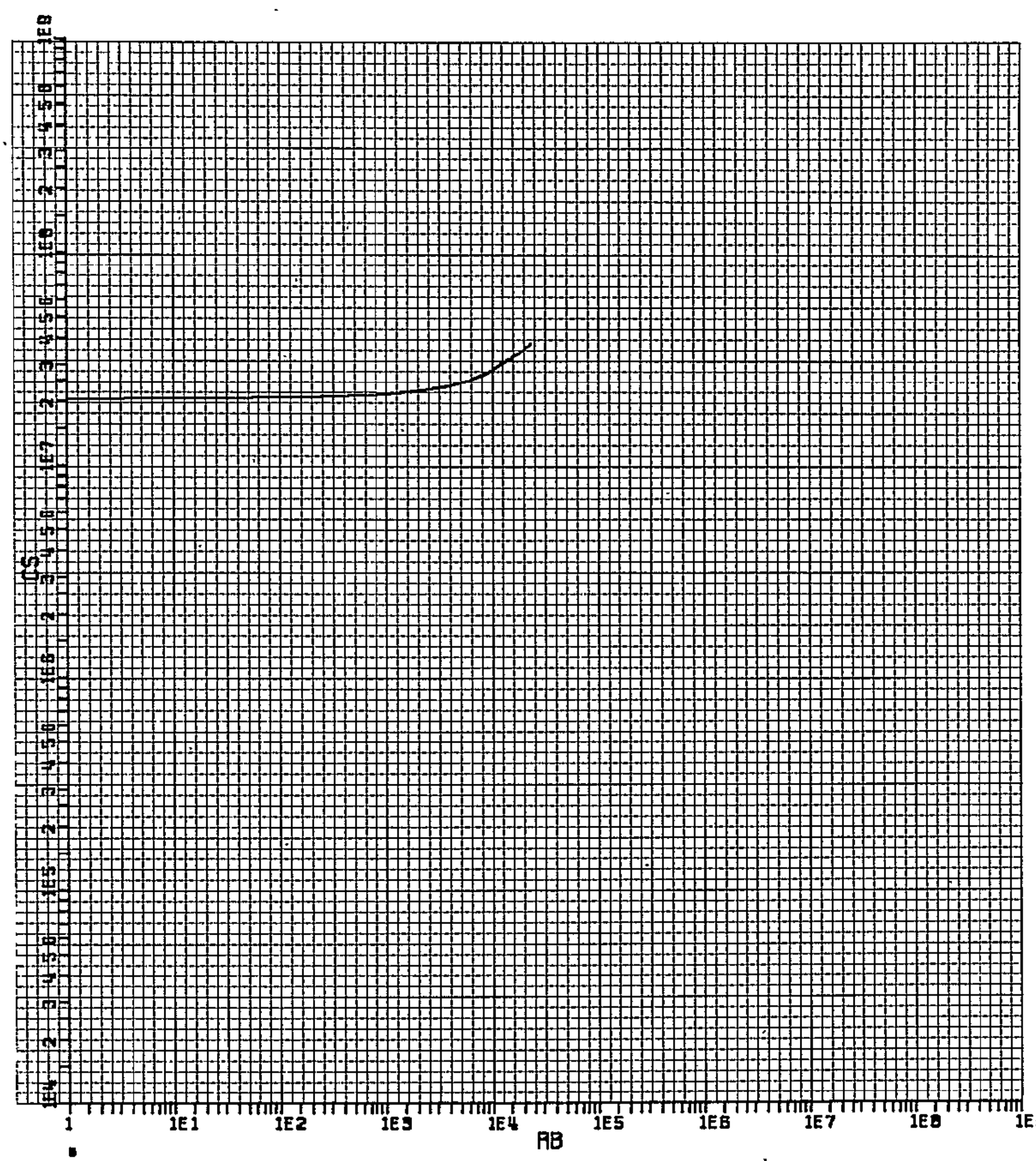
SYSTEM BURDEN CONSTANTS

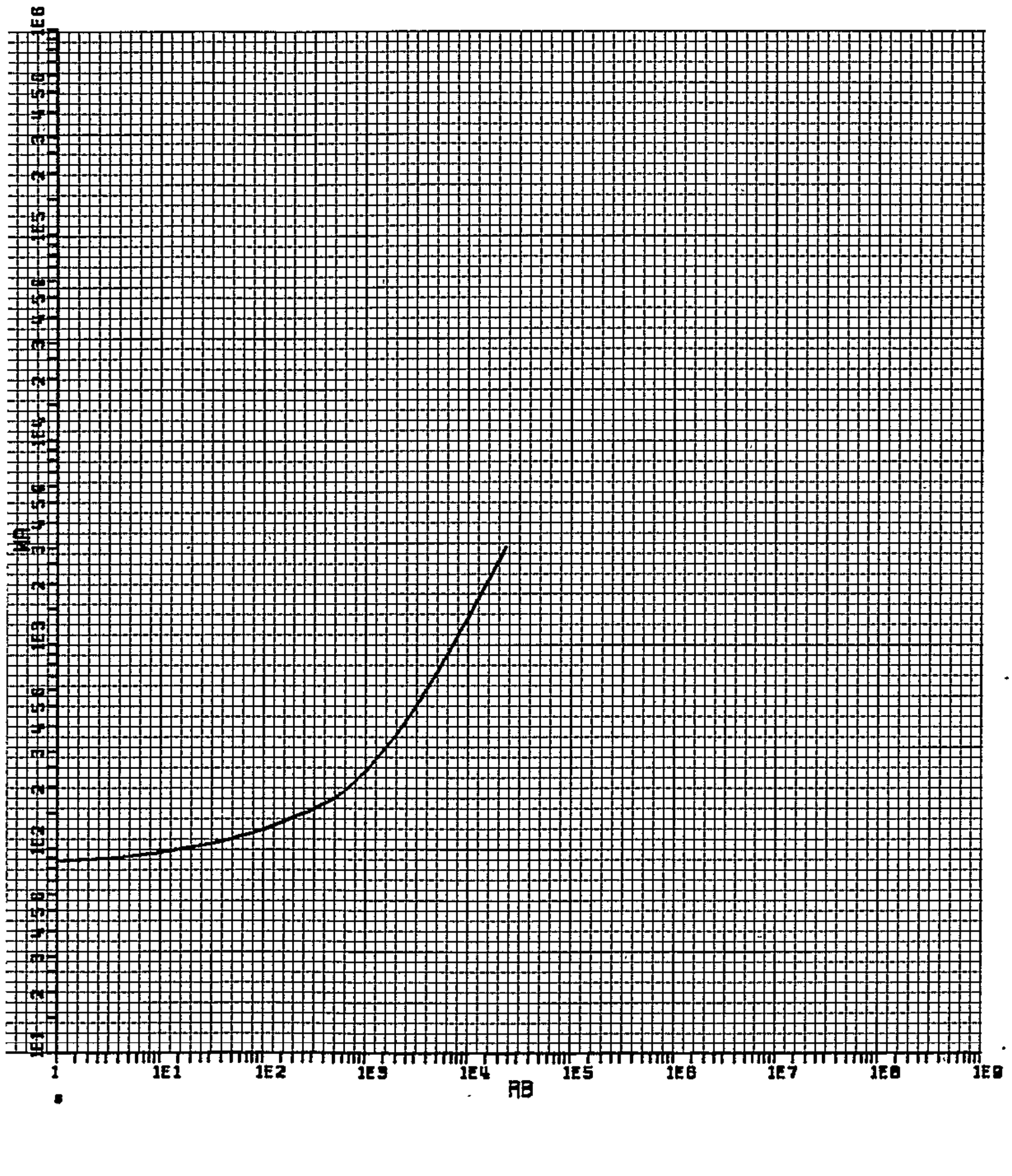
KMT	0.	KNT	0.	KQT	0.71000E 05	KMR	0.	KNR	0.	KQR	0.
KGT	0.96000E 02	KHT	0.13120E 03	KJT	0.16621E 05						

PARAMETER CONSTRAINTS

DTI	0.	GTI	0.17400E 03	DRI	0.	GRI	0.19000E 07	PTI	0.50000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.19000E 07	PTM	0.	THERM	0.10000E-02
DTB	0.	GTB	0.34800E 03	DRB	0.	GRB	0.19000E 07	PTB	0.10000E 04	THERB	0.10000E-02


GT
GB
PT
THETA=1.E+05
GT, GB
THETA(1), PT
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9


CS
AB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9


WA
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9

Example E. Mars Spacecraft Transmitter to Earth Receiver Link

13 cm wavelength

PCM phase shift keying

Thermal noise limited operation

Transmitter system weight and fabrication cost jointly optimized.

Parameters to be optimized:

a. Transmitter antenna diameter

b. Transmitter power

Fixed parameters:

a. Receiver antenna diameter at 64 meters

b. Receiver field of view of 1 milliradian

Parameter stops:

a. Transmitter power at 1 kw

Data values:

a. Signal-to-noise ratio: 20, 30, 40, 50

b. Transmitter antenna efficienty = 60 percent

c. Revised transmitter burdens (1980 estimates)

NAME ________ DATE ________ PROBLEM EXAMPLE E

COPTRAN INSTRUCTIONS AND DATA

INSTRUCTION TYPE		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	1	S	P	X	M	T	R																			SPACECRAFT TRANSMITTER
2	2	E	A	R	C	V	R																			EARTH RECEIVER
3	3	R	A	N	M	A	R																			MARS RANGE
4	4	L	A	M	1	3	C																			13 CM TRANSMISSION WAVELENGTH
5	5	B	K	G	A	L	T																			GALACTIC BACKGROUND
6	6	P	C	M	/	P	M																			PCM PHASE SHIFT KEYING
6	7	R	A	D	H	O	M																			COHERENT RADIO HOMODYNE DETECTION
7	8	X	M	W	T	O	P																			XMTR SYSTEM WEIGHT AND XMTR SYSTEM
7	9	X	M	F	C	O	P																			FABRICATION COST JOINTLY OPTIMIZED
8	10	G	T	G	R	O	P																			XMTR AND RECEIVER ANTENNA GAIN OPTIMIZATION
9	11	N	X	P	W	S	A																			RTG XMTR POWER SUPPLY BURDENS
10	12	R	B	F	R	Q	O																			DATA POINTS AT $R_B = 10^0,\ 0.2 \times 10^1,\ 0.3 \times 10^1$
10	13	R	B	I	N	T	O																			$\ldots,\ 10^7$ BITS PER SECOND
10	14	R	B	F	I	N	7																			
WORTH SET	15	W	O	R	T	H																				PLOT AND PRINT THE WORTH VALUES
	16	W	A																							OF W_A FOR THE SET OF CASES
	17	P	L	T	W	T	H																			TO BE RUN
	18	P	R	T	W	T	H																			
11	19	P	R	T	D	A	T																			PRINT SYSTEM DATA AND CONSTANTS
12	20	P	L	T	O	P	T																			PLOT OPTIMUM SYSTEM PARAMETERS
13	21	E	N	D	I	N	S																			END OF COPTRAN INSTRUCTIONS
DATA	22	R	H	O	T										.	6										TRANSMITTER ANTENNA EFFICIENCY
DATA	23	K	P	T									9	6	.											
DATA	24	K	W	T											.	0	8									REVISED TRANSMITTER BURDENS
DATA	25	K	H												.	4	6									

NAME ____________ DATE ____________ PROBLEM EXAMPLE E (continued)

COPTRAN INSTRUCTIONS AND DATA

INSTRUCTION		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
DATA	1	K	X												.	5	6			E	-	0	2			REVISED TRANSMITTER BURDENS
DATA	2	K	E												.	2	5									
DATA	3	C	X											8	.	7	5			E	+	0	3			
DATA	4	C	H											6	.	8	8			E	+	0	3			
DATA	5	W	K	P										2	.	5	0									
DATA	6	W	K	H										0	.											
DATA	7	G	T											1	.											
DATA	8	H	T											1	.											
DATA	9	J	T											1	.											
DATA	10	G	R	M										1	.	9				E	+	0	6			
DATA	11	P	T	B											.	1				E	+	0	4			
DATA	12	T	H	E	R	M									.	1				E	-	0	2			
INCREMENT SET	13	N	C	R	M	N	T						1	0	.											INCREMENT S/N FROM 20 TO 50 IN STEP SIZES OF 10
	14	S	N										2	0	.											
	15	F	I	N	A	L	E						5	0	.											
14	16	E	N	D	D	A	T																			END OF COPTRAN DATA
15	17	E	N	D	C	A	S																			END OF CASES
	18																									
	19																									
	20																									
	21																									
	22																									
	23																									
	24																									
	25																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 13 CM
GALACTIC BACKGROUND
PCM PHASE MODULATION
RADIO HOMODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA GAIN AND RECEIVER ANTENNA GAIN OPTIMIZATOON


*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
BANMAR
CAM10C
BKGACT
PCM/PM
RADHOM
XMWTOP
XMFCOP
GTGROP
NXPWGA
RBFR00

RBINT0
RBFIN7
WORTH
WA
PLTWTH
PRTWTH
PRTDAT
PLTDAT
ENDINS
BHOT          .600
KPT        98.
KWT           .08
KH            .46
KX            .56  E-02
KE            .25
CX           8.75  E 03
CH           6.88  E 03
WKP          2.50
WKH          0.
GT           1.
HT           1.
JT           1.
GRM          1.9   E 06
PTB           .10  E 04
THERM         .10  E-02
NCRMNT     10.
SN         20.
FINACE     50.
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	HTHT	520.00000	HDT	0.01350	CKT	5000.00	WKT	0.	MT	1.00	NT	1.00000
RECEIVER ANTENNA	HTHR	0.06600	HDR	0.	CKR	0.	WKR	0.	MR	1.35	NR	0.
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.75000	KPQT	10.00000	CAT	140000.	WBT	10.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	0.	KWAR	0.	KPQR	0.	CAR	0.	WBR	0.	QR	0.
TRANSMITTER	KPT	96.00000	KWT	0.08000	KH	0.46000	KX	0.00560	KE	0.25000	CKP	17500.00
	CKH	23800.	WKP	2.500	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.	KM	0.	KPM	0.	CKM	0.	WKM	0.		
DEMODULATION EQUIPMENT	KFD	0.	KD	0.	KPD	0.	CKD	0.	WKD	0.		
TRANSMITTER POWER SUPPLY	KST	3000.000	KWST	0.700000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.10000E 14	LAMBDA	0.13000E 02	S/N	0.20000E 02	C/N	0.	USBREU	0.	TAU-I	0.75000E 00
TAU-R	0.35000E 00	TAU-A	0.95000E 00	TE	0.27000E 02	ETA	0.	RL	0.	LMBD-I	0.
QB	0.	RHO-I	0.60000E 00	RHO-R	0.80000E 00						

****

****

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.	KM	0.	KR	0.89534E-07	KS	0.

****

****

SYSTEM BURDEN CONSTANTS

KMI	0.	KNT	0.	KOT	0.71000E 05	KMR	0.	KNR	0.	KOR	0.
KGI	0.96000E 02	KHT	0.13120E 03	KJT	0.16621E 05						

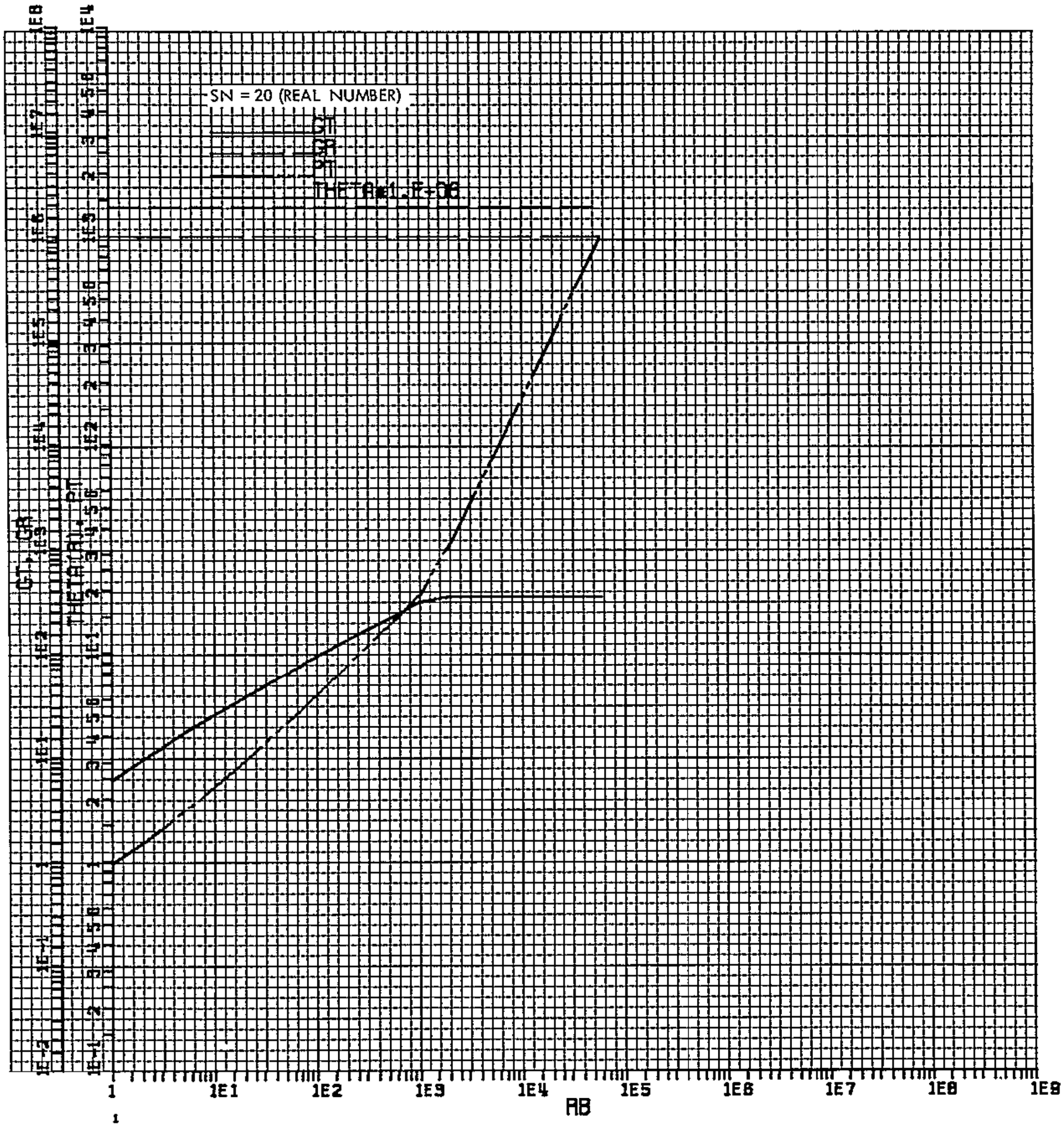
****

****

PARAMETER CONSTRAINTS

DTI	0.	GTI	0.17400E 03	DRI	0.	GRI	0.19000E 07	PTI	0.50000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.19000E 07	PTM	0.	THERM	0.10000E-02
DTB	0.	GTB	0.34800E 03	DRB	0.	GRB	0.19000E 07	PTB	0.10000E 04	THERB	0.10000E-02

****


SN = 20 (REAL NUMBER)
CT
CR
PT
THETA=1.E+06
CT , CR
THETA(R)+ PT
RB

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 13 CM
GALACTIC BACKGROUND
PCM PHASE MODULATION
RADIO HOMODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA GAIN AND RECEIVER ANTENNA GAIN OPTIMIZATION

*** FORTRAN PROGRAM ***

SPXMTR
EARCVR
RANMAR
LAM13C
BKGACT
PCM/PM
RADHOM
XMWTOP
XMFCOP
GTGROP
NXPWDA
RBFRQO
RBINTO
RBFIN7
WORTH
WA
PLTWTH
PRTWTH
PRTDAT
PLTOPT
ENDINS
RHOT       .600
RPT      98.
RWT        .08
RH         .46
RX         .56  E-02
RE         .25
EX        8.75  E 03
EH        6.88  E 03
WKP       2.50
WKH       0.
GT        1.
HT        1.
JT        1.
GRM       1.9   E 06
PTB        .10  E 04
THERM      .10  E-02
NCRMNT   10.
SN       20.
FINAGE   50.
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	HTHT	520.00000	HDT	0.01350	CKT	5000.00	WKT	0.	MT	1.00	NT	1.00000
RECEIVER ANTENNA	HTHR	0.06600	HDR	0.	CKR	0.	WKR	0.	MR	1.35	NR	0.
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.75000	KPQT	10.00000	CAT	140000.	WBT	10.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	0.	KWAR	0.	KPQR	0.	CAR	0.	WBR	0.	QR	0.
TRANSMITTER	KPT	96.00000	KWT	0.08000	KH	0.46000	KX	0.00560	KE	0.25000	CKP	17500.00
	CKH	23800.	WKP	2.500	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.	KM	0.	KPM	0.	CKM	0.	WKM	0.		
DEMODULATION EQUIPMENT	KFD	0.	KD	0.	KPD	0.	CKD	0.	WKD	0.		
TRANSMITTER POWER SUPPLY	KST	3000.000	KWST	0.700000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.10000E 14	LAMBDA	0.13000E 02	S/N	0.30000E 02	C/N	0.	USBREQ	0.	TAU-T	0.75000E 00
TAU-R	0.35000E 00	TAU-A	0.95000E 00	TE	0.27000E 02	ETA	0.	RL	0.	LMBD-I	0.
QB	0.	RHO-T	0.60000E 00	RHO-R	0.80000E 00						

****

****

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.	KM	0.	KR	0.59689E-07	KS	0.

****

****

SYSTEM BURDEN CONSTANTS

KMI	0.	KNT	0.	KQT	0.71000E 05	KMR	0.	KNR	0.	KQR	0.
KGI	0.96000E 02	KHT	0.13120E 03	KJT	0.16621E 05						

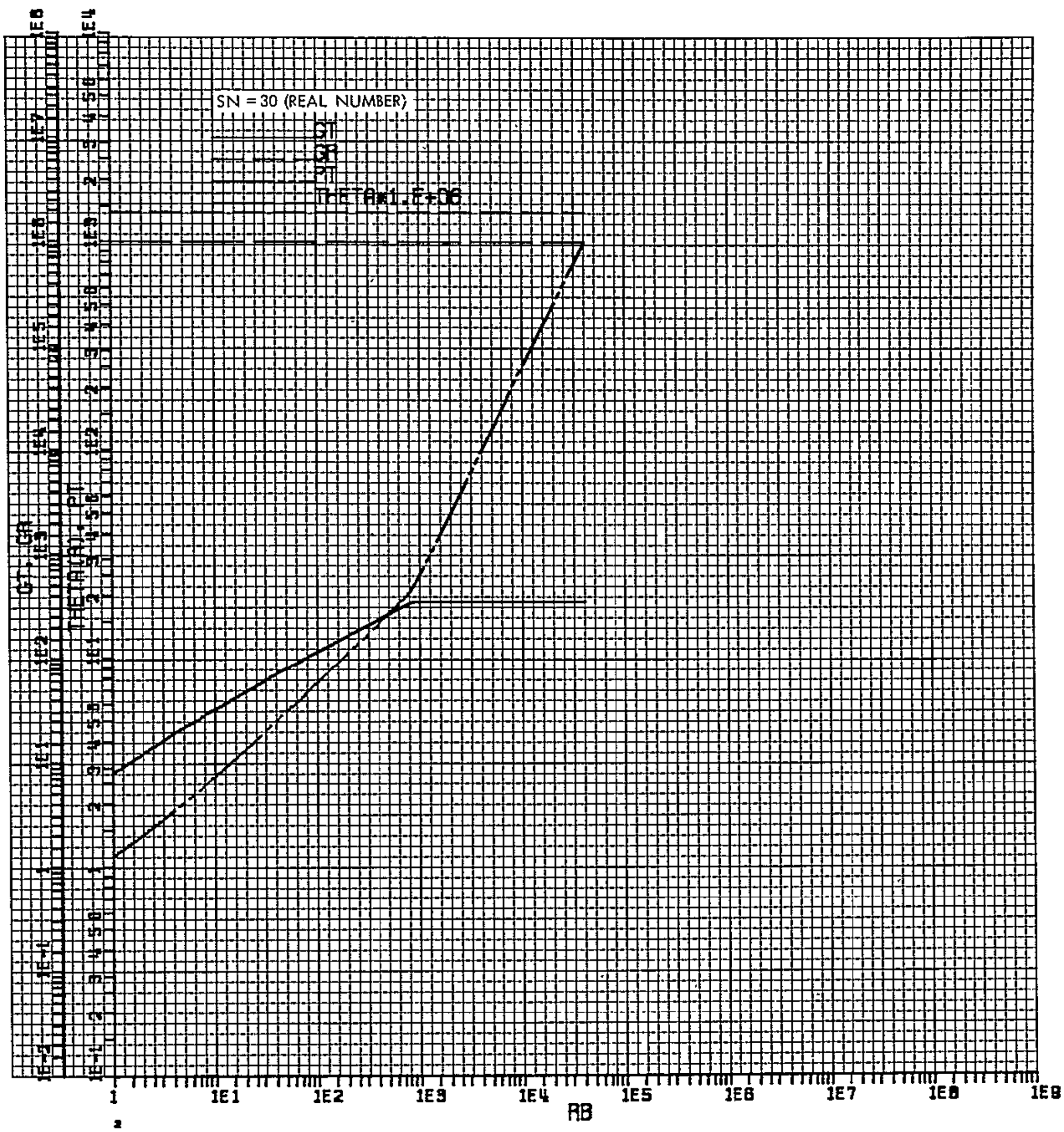
****

****

PARAMETER CONSTRAINTS

DTI	0.	GTI	0.17400E 03	DRI	0.	GRI	0.19000E 07	PTI	0.50000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.19000E 07	PTM	0.	THERM	0.10000E-02
DTB	0.	GTB	0.34800E 03	DRB	0.	GRB	0.19000E 07	PTB	0.10000E 04	THERB	0.10000E-02

****


SN = 30 (REAL NUMBER)
GT
GR
PT
THETA*1.E+06
GT, GR
THETA(A), PT
RB

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 13 CM
GALACTIC BACKGROUND
PCM PHASE MODULATION
RADIO HOMODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA GAIN AND RECEIVER ANTENNA GAIN OPTIMIZATION

*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
RANMAR
CAM13C
BKGACT
PCM/PM
RADHOM
XMWTOP
XMFCOP
GTGROP
NXPWSA

RBFR00
RBINT0
RBFIN7
WORTH
WA
PLTWTH
PRTWTH
PRTDAT
PLTOPT
ENDINS
RHOT       .608
RPT     98.
RWT        .08
RH         .46
RX         .56  E-02
RE         .25
EX       8.75  E 03
EH       0.38  E 03
WKP      2.50
RKH      0.
QT       1.
HT       1.
YT       1.
GRM      1.5   E 06
PTB        .10  E 04
THERM      .10  E-02
NCRMNT  10.
SN      20.
KINACE  50.
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	HTHT	520.00000	HDT	0.01350	CKT	5000.00	WKT	0.	MT	1.00	NT	1.00000
RECEIVER ANTENNA	HTHR	0.06600	HDR	0.	CKR	0.	WKR	0.	MR	1.35	NR	0.
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.75000	KPQT	10.00000	CAT	140000.	WBT	10.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	0.	KWAR	0.	KPQR	0.	CAR	0.	WBR	0.	QR	0.
TRANSMITTER	KPT	96.00000	KWT	0.08000	KH	0.46000	KX	0.00560	KE	0.25000	CKP	17500.00
	CKH	23800.	WKP	2.500	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.	KM	0.	KPM	0.	CKM	0.	WKM	0.		
DEMODULATION EQUIPMENT	KFD	0.	KD	0.	KPD	0.	CKD	0.	WKD	0.		
TRANSMITTER POWER SUPPLY	KST	3000.000	KWST	0.700000	CKE	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.10000E 14	LAMBDA	0.13000E 02	S/N	0.40000E 02	C/N	0.	USBREQ	0.	TAU-T	0.75000E 00
TAU-R	0.35000E 00	TAU-A	0.95000E 00	TE	0.27000E 02	ETA	0.	RL	0.	LMBD-I	0.
QB	0.	RHO-T	0.60000E 00	RHO-R	0.80000E 00						

****

****

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.	KM	0.	KR	0.44767E-07	KS	0.

****

****

SYSTEM BURDEN CONSTANTS

KMT	0.	KNT	0.	KOT	0.71000E 05	KMR	0.	KNR	0.	KOR	0.
KGT	0.96000E 02	KHT	0.13120E 03	KJT	0.16621E 05						

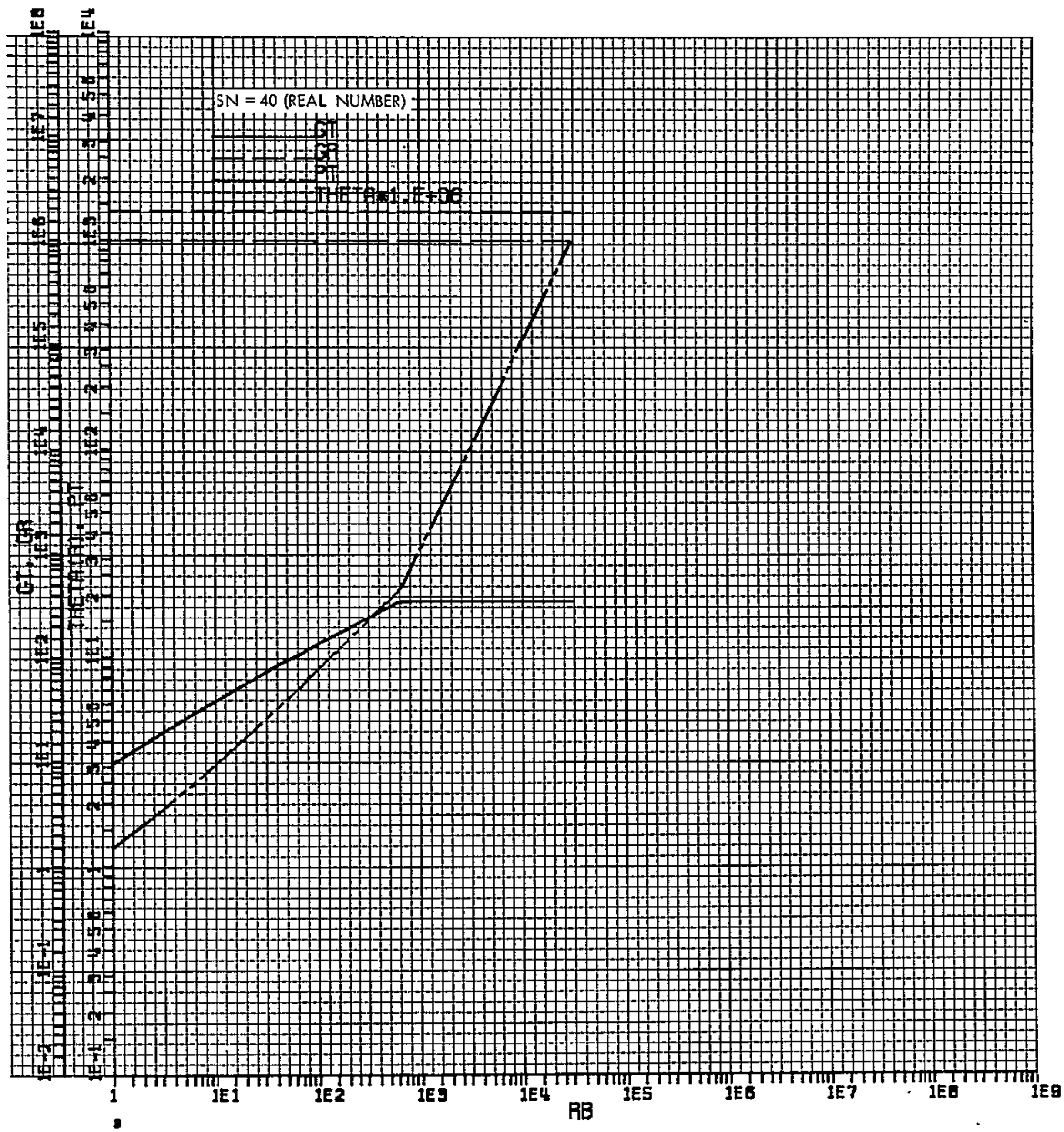
****

****

PARAMETER CONSTRAINTS

DTI	0.	GTI	0.17400E 03	DRI	0.	GRI	0.19000E 07	PTI	0.50000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.19000E 07	PTM	0.	THERM	0.10000E-02
DTB	0.	GTB	0.34800E 03	DRB	0.	GRB	0.19000E 07	PTB	0.10000E 04	THERB	0.10000E-02

****


SN = 40 (REAL NUMBER)
GT
QR
PT
THETA*1.E+06
GT, QR
THETA(A), PT
RB

```
SPACECRAFT TRANSMITTER
EARTH RECEIVER
MARS RANGE (1.E8 KM)
TRANSMISSION WAVELENGTH LAMBDA = 13 CM
GALACTIC BACKGROUND
PCM PHASE MODULATION
RADIO HOMODYNE DETECTION
TRANSMITTER WEIGHT OPTIMIZATION
TRANSMITTER FABRICATION COST OPTIMIZATION
TRANSMITTER ANTENNA GAIN AND RECEIVER ANTENNA GAIN OPTIMIZATION

*** COPTRAN PROGRAM ***

SPXMTR
EARCVR
RANMAR
LAM13C
BKGACT
PCM/PM
RADHOM
XMWTOP
XMFCOP
GTGROP
NXPWSA

RBFR00
RBINT0
RBFIN7
WORTH
WA
PLTWTH
PRTWTH
PRTDAT
PLTOPT
ENDINS
RHOT          .600
RPT          90.
KWT           .08
KH            .46
KX            .56  E.02
KE            .25
CX           8.75  E 03
CH           6.88  E 03
WKP          2.50
WKH           0.
GT            1.
HT            1.
XT            1.
GRM          1.9   E 06
PTB           .10  E 04
THERM         .10  E.02
NCRMNT       10.
SN           20.
FINACE       50.
ENDDAT
```

SYSTEM BURDENS DATA

TRANSMITTER ANTENNA	HTHT	520.00000	HDT	0.01350	CKT	5000.00	WKT	0.	MT	1.00	NT	1.00000
RECEIVER ANTENNA	HTHR	0.06600	HDR	0.	CKR	0.	WKR	0.	MR	1.35	NR	0.
TRANSMITTER ACQUISITION AND TRACK SYSTEM	KAT	71000.	KWAT	0.75000	KPQT	10.00000	CAT	140000.	WBT	10.000	QT	0.30000
RECEIVER ACQUISITION AND TRACK SYSTEM	KAR	0.	KWAR	0.	KPQR	0.	CAR	.0.	WBR	0.	QR	0.
TRANSMITTER	KPT	96.00000	KWT	0.08000	KH	0.46000	KX	0.00560	KE	0.25000	CKP	17500.00
	CKH	23800.	WKP	2.500	WKH	0.	JT	1.000	GT	1.00000	HT	1.00000
MODULATION EQUIPMENT	KFM	0.	KM	0.	KPM	0.	CKM	0.	WKM	0.		
DEMODULATION EQUIPMENT	KFD	0.	KD	0.	KPD	0.	CKD	0.	WKD	0.		
TRANSMITTER POWER SUPPLY	KST	3000.000	KWST	0.700000	CKF	0.	WKE	0.				
RECEIVER POWER SUPPLY	KSR	25.000	KWSR	0.	CKF	10000.	WKF	0.				
BOOSTER BURDENS	KSA	1640.000	KSB	1640.000								

****

SYSTEM PHYSICAL DATA

R	0.10000E 14	LAMBDA	0.13000E 02	S/N	0.50000E 02	C/N	0.	USBREQ	0.	TAU-T	0.75000E 00
TAU-R	0.35000E 00	TAU-A	0.95000E 00	TE	0.27000E 02	ETA	0.	RL	0.	LMBD-I	0.
QB	0.	RHO-T	0.60000E 00	RHO-R	0.80000E 00						

****

****

SIGNAL-TO-NOISE RATIO CONSTANTS

K	0.	KN	0.	KM	0.	KR	0.35814E-07	KS	0.

****

****

SYSTEM BURDEN CONSTANTS

KMT	0.	KNT	0.	KQT	0.71000E 05	KMR	0.	KNR	0.	KQR	0.
KGT	0.96000E 02	KHT	0.13120E 03	KJT	0.16621E 05						

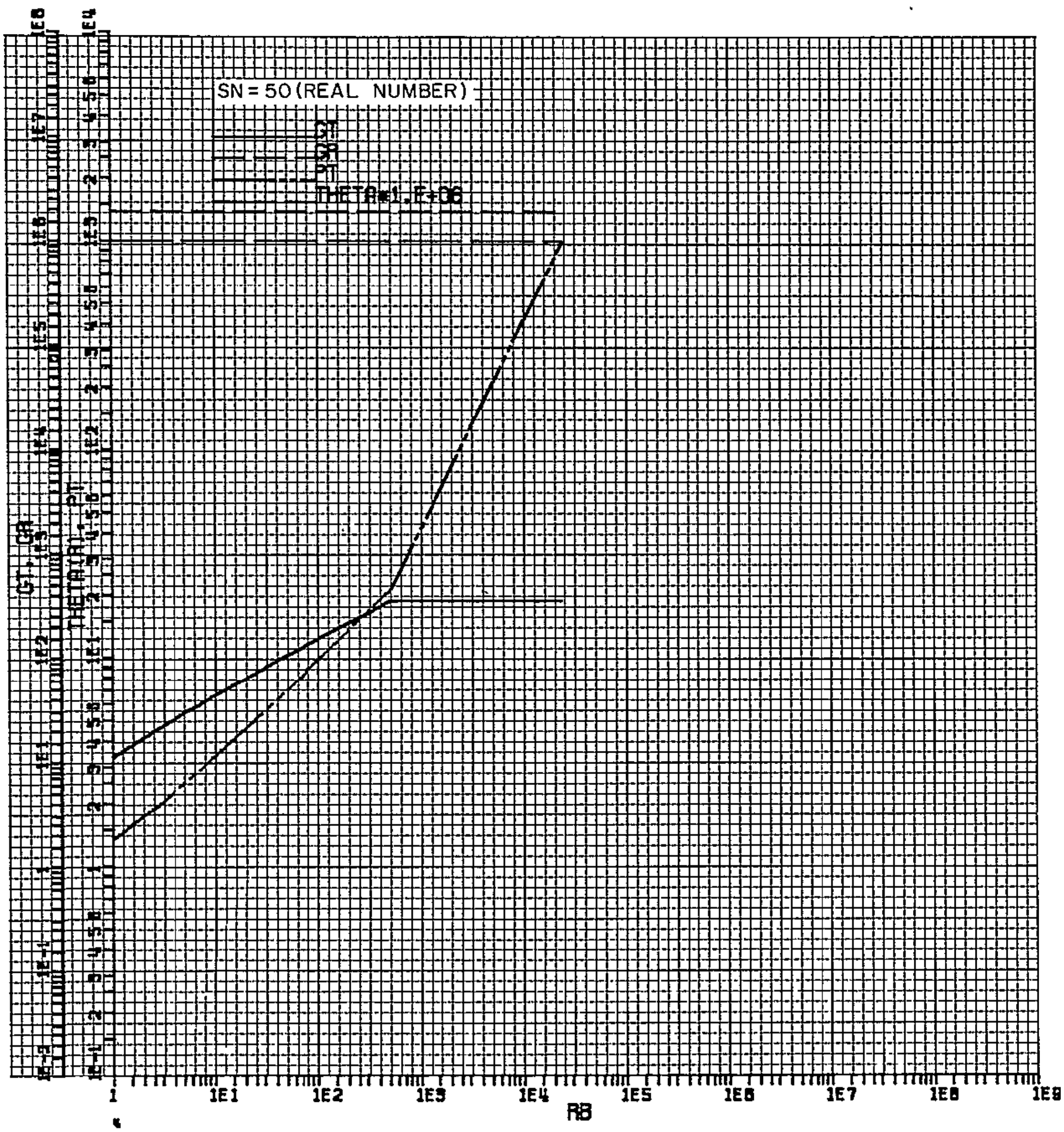
****

****

PARAMETER CONSTRAINTS

DTI	0.	GTI	0.17400E 03	DRI	0.	GRI	0.19000E 07	PTI	0.50000E 03	THERI	0.10000E-02
DTM	0.	GTM	0.	DRM	0.	GRM	0.19000E 07	PTM	0.	THERM	0.10000E-02
DTB	0.	GTB	0.34800E 03	DRB	0.	GRB	0.19000E 07	PTB	0.10000E 04	THERB	0.10000E-02

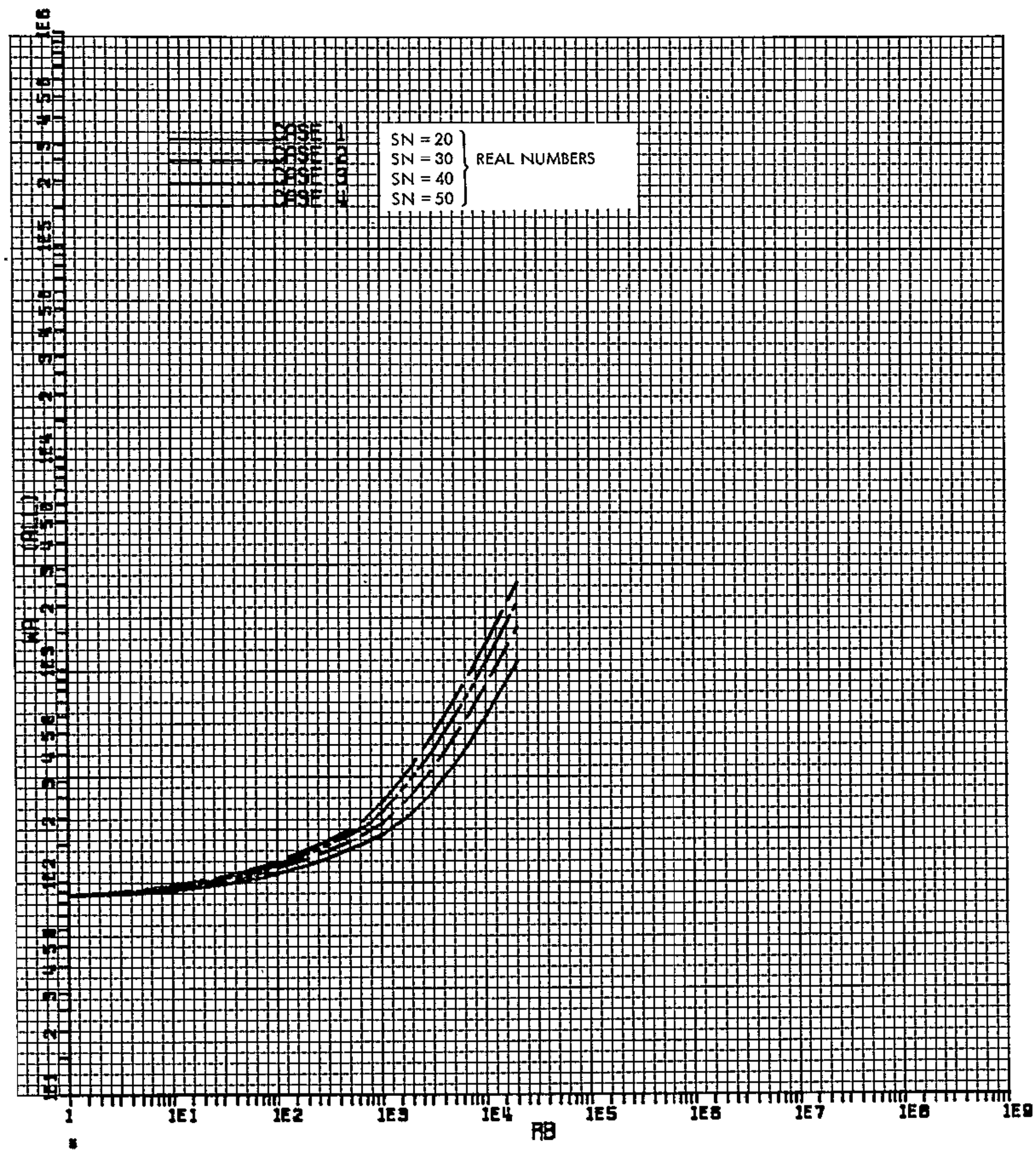
****

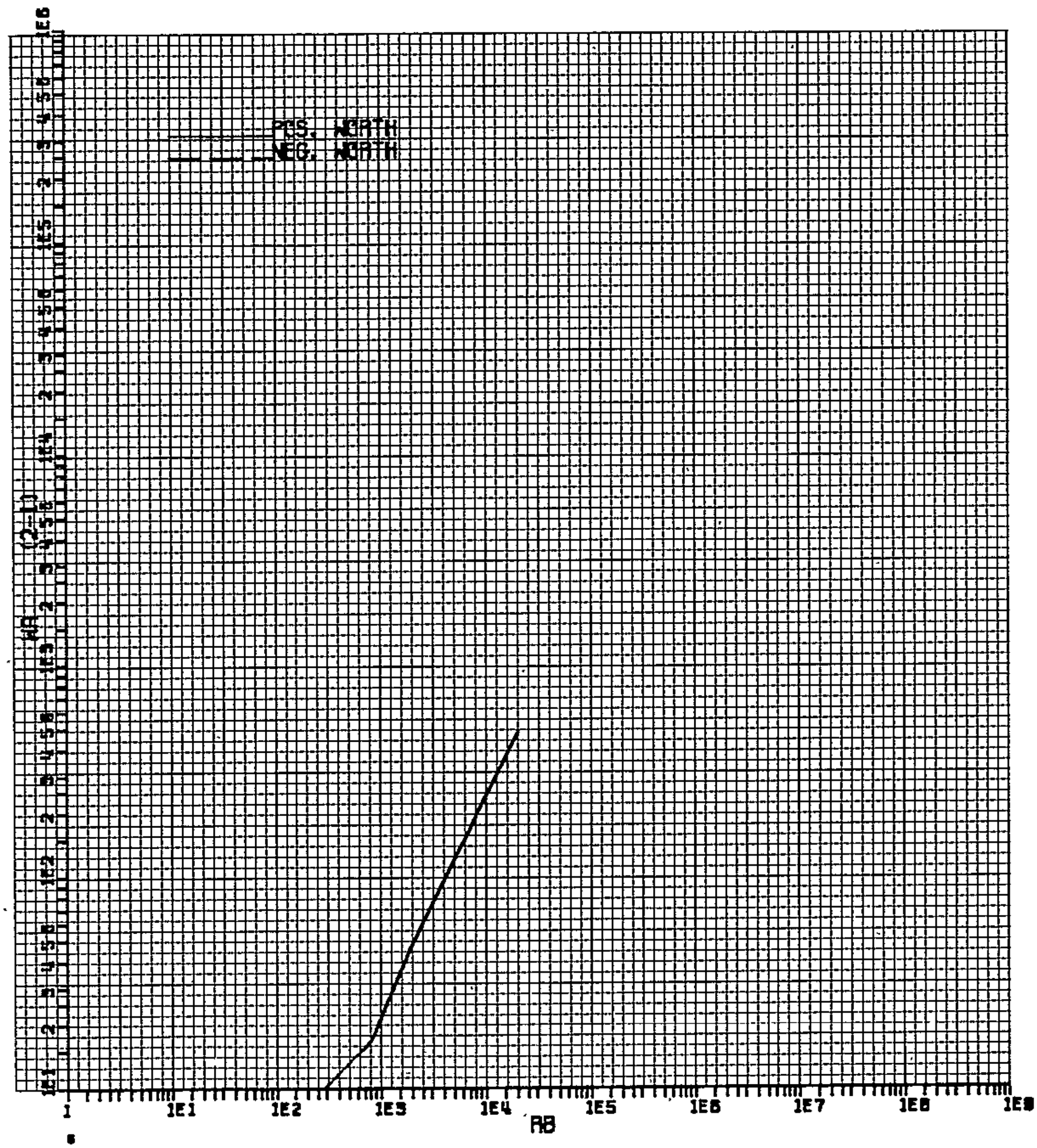

SN = 50 (REAL NUMBER)
CT
CR
PT
THETA*1.E+06
CT, CR
THETA(R), PT
RB

WORTH PARAMETER - WA

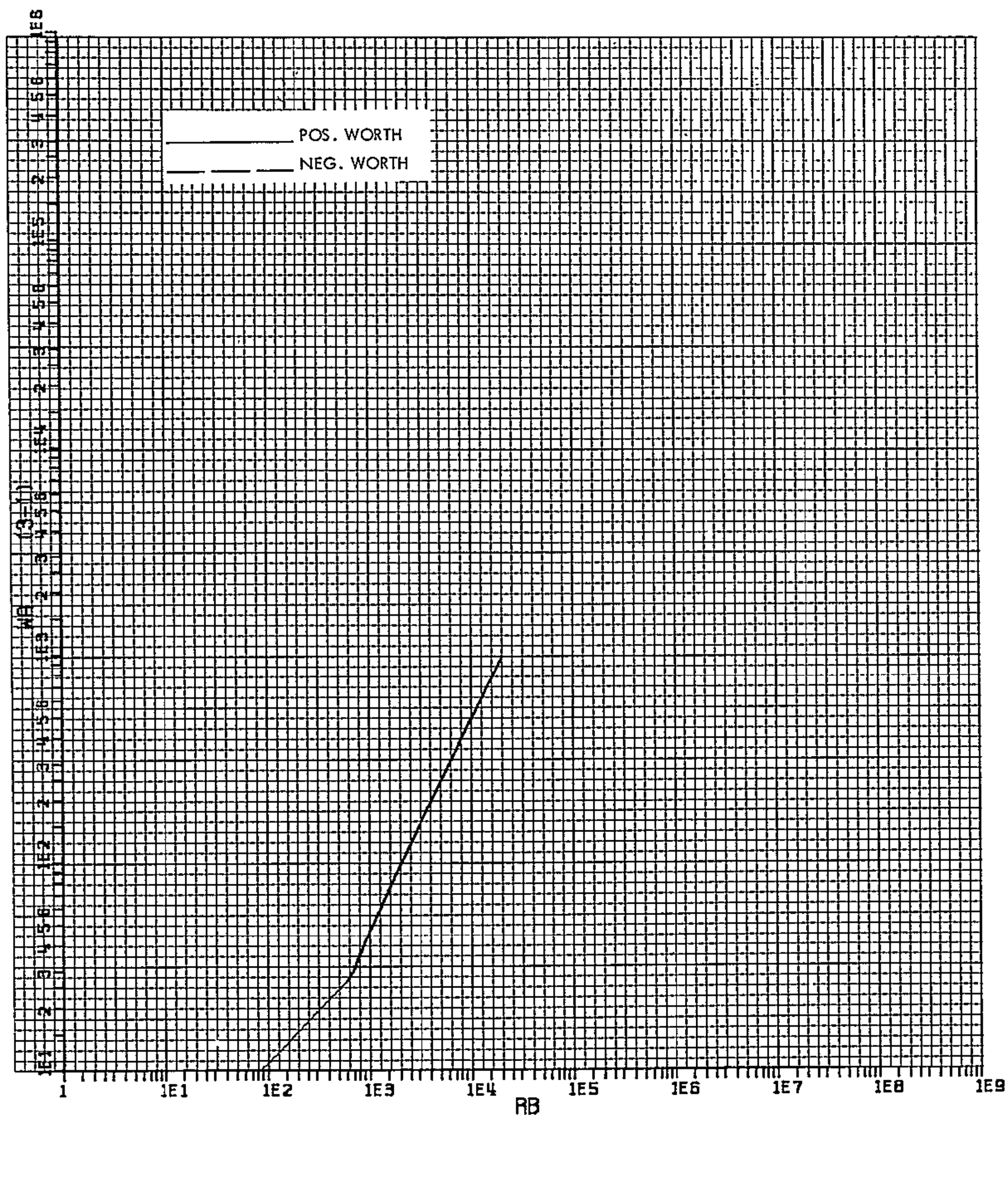
*** WORTH VALUES ***

R3	2-1	3-1	4-1	3-2	4-2	4-3
0.100000E 01	0.575438E 00	0.106403E 01	0.149650E 01	0.488597E 00	0.921066E 00	0.432469E 00
0.200007E 01	0.824754E 00	0.152360E 01	0.214121E 01	0.698846E 00	0.131645E 01	0.617607E 00
0.300001E 01	0.101604E 01	0.187596E 01	0.263532E 01	0.859919E 00	0.161928E 01	0.759361E 00
0.400000E 01	0.117712E 01	0.217264E 01	0.305132E 01	0.995515E 00	0.187420E 01	0.878682E 00
0.500009E 01	0.131885E 01	0.243367E 01	0.341736E 01	0.111482E 01	0.209851E 01	0.983686E 00
0.600000E 01	0.144693E 01	0.266954E 01	0.374808E 01	0.122261E 01	0.230115E 01	0.107854E 01
0.700000E 01	0.156459E 01	0.288624E 01	0.405194E 01	0.132165E 01	0.248736E 01	0.116570E 01
0.800000E 01	0.167403E 01	0.308781E 01	0.433461E 01	0.141378E 01	0.266058E 01	0.124679E 01
0.900000E 01	0.177676E 01	0.327703E 01	0.459995E 01	0.150027E 01	0.282319E 01	0.132292E 01
0.100000E 02	0.187389E 01	0.345592E 01	0.485082E 01	0.158204E 01	0.297693E 01	0.139489E 01
0.200006E 02	0.265662E 01	0.489779E 01	0.687299E 01	0.224117E 01	0.421637E 01	0.197519E 01
0.300000E 02	0.325617E 01	0.600236E 01	0.842226E 01	0.274619E 01	0.516609E 01	0.241990E 01
0.400000E 02	0.376121E 01	0.693290E 01	0.972750E 01	0.317168E 01	0.596629E 01	0.279461E 01
0.500016E 02	0.420618E 01	0.775203E 01	0.108766E 02	0.354585E 01	0.667047E 01	0.312461E 01
0.600000E 02	0.460787E 01	0.849292E 01	0.119158E 02	0.388506E 01	0.730795E 01	0.342290E 01
0.700000E 02	0.497738E 01	0.917380E 01	0.128709E 02	0.419643E 01	0.789357E 01	0.369714E 01
0.800000E 02	0.532124E 01	0.980744E 01	0.137598E 02	0.448620E 01	0.843858E 01	0.395238E 01
0.900001E 02	0.564415E 01	0.104025E 02	0.145946E 02	0.475832E 01	0.895040E 01	0.419207E 01
0.100000E 03	0.594953E 01	0.109652E 02	0.153840E 02	0.501567E 01	0.943443E 01	0.441876E 01
0.200005E 03	0.841356E 01	0.155060E 02	0.217541E 02	0.709241E 01	0.133405E 02	0.624810E 01
0.300000E 03	0.103034E 02	0.189887E 02	0.266400E 02	0.868531E 01	0.163366E 02	0.765133E 01
0.400000E 03	0.118963E 02	0.219244E 02	0.307586E 02	0.100281E 02	0.188623E 02	0.883421E 01
0.500000E 03	0.132996E 02	0.245106E 02	0.343879E 02	0.112109E 02	0.210882E 02	0.987729E 01
0.600000E 03	0.145682E 02	0.268489E 02	0.407890E 02	0.122807E 02	0.262207E 02	0.139401E 02
0.700000E 03	0.157347E 02	0.307018E 02	0.478282E 02	0.149671E 02	0.320935E 02	0.171264E 02
0.800001E 03	0.168208E 02	0.356541E 02	0.552272E 02	0.188333E 02	0.384064E 02	0.195731E 02
0.900001E 03	0.188808E 02	0.409005E 02	0.629202E 02	0.220197E 02	0.440394E 02	0.220197E 02
0.100000E 04	0.219267E 02	0.463930E 02	0.708593E 02	0.244663E 02	0.489326E 02	0.244663E 02
0.200000E 04	0.489326E 02	0.978653E 02	0.146798E 03	0.489326E 02	0.978653E 02	0.489326E 02
0.300000E 04	0.733990E 02	0.146798E 03	0.220197E 03	0.733990E 02	0.146798E 03	0.733990E 02
0.400000E 04	0.978653E 02	0.195731E 03	0.293596E 03	0.978653E 02	0.195731E 03	0.978653E 02
0.500000E 04	0.122332E 03	0.244663E 03	0.366995E 03	0.122332E 03	0.244663E 03	0.122332E 03
0.600000E 04	0.146798E 03	0.293596E 03	0.440394E 03	0.146798E 03	0.293596E 03	0.146798E 03
0.700000E 04	0.171264E 03	0.342528E 03	0.513793E 03	0.171264E 03	0.342528E 03	0.171264E 03
0.800000E 04	0.195731E 03	0.391461E 03	0.587192E 03	0.195731E 03	0.391461E 03	0.195731E 03
0.900000E 04	0.220197E 03	0.440394E 03	0.660591E 03	0.220197E 03	0.440394E 03	0.220197E 03
0.100000E 05	0.244663E 03	0.489326E 03	0.733990E 03	0.244663E 03	0.489326E 03	0.244663E 03
0.200000E 05	0.489326E 03	0.978653E 03	0.146798E 04	0.489326E 03	0.978653E 03	0.489326E 03

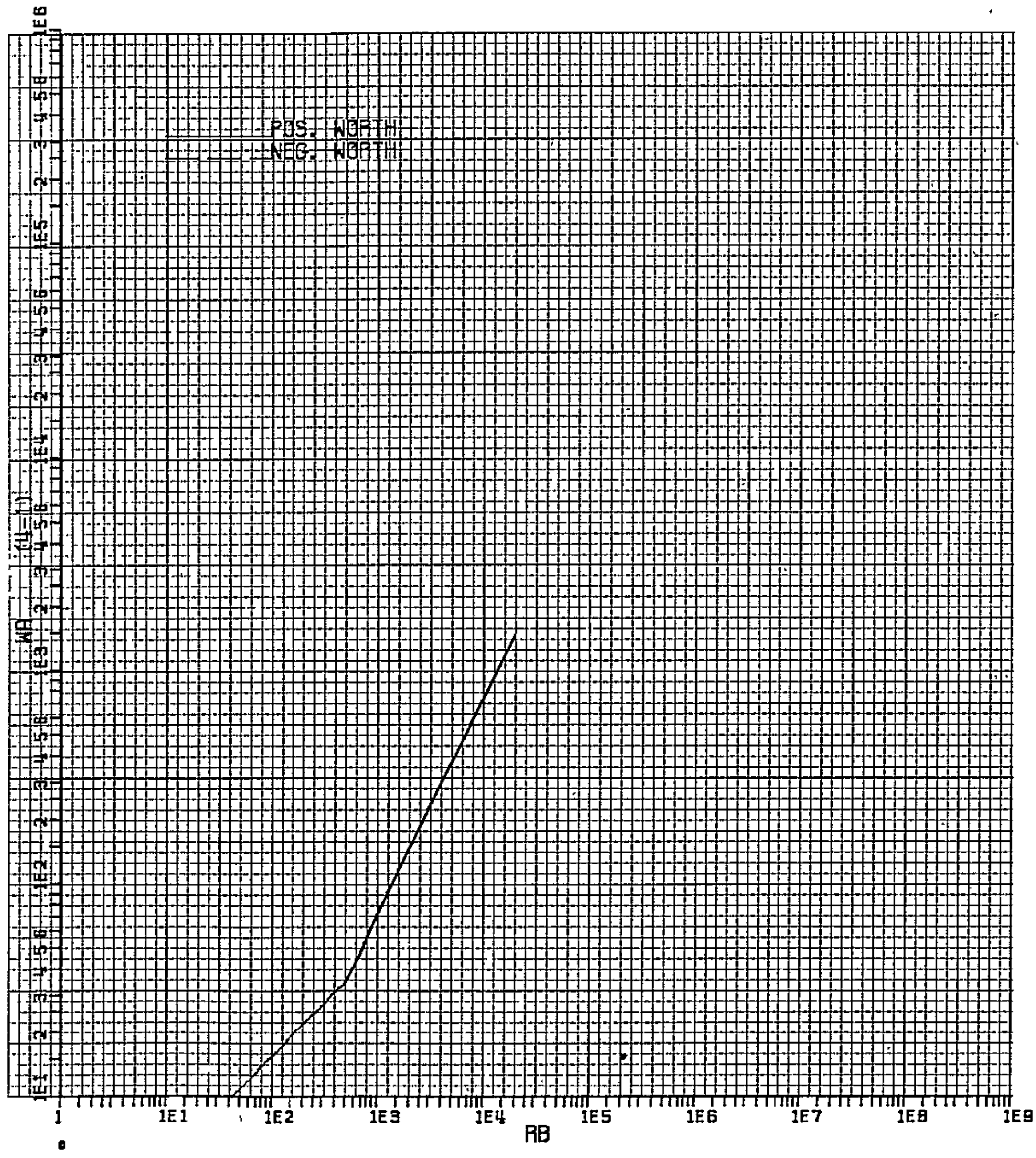

CASE 1
CASE 2
CASE 3
CASE 4
SN = 20
SN = 30
SN = 40
SN = 50
REAL NUMBERS
KA (ALL)
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9



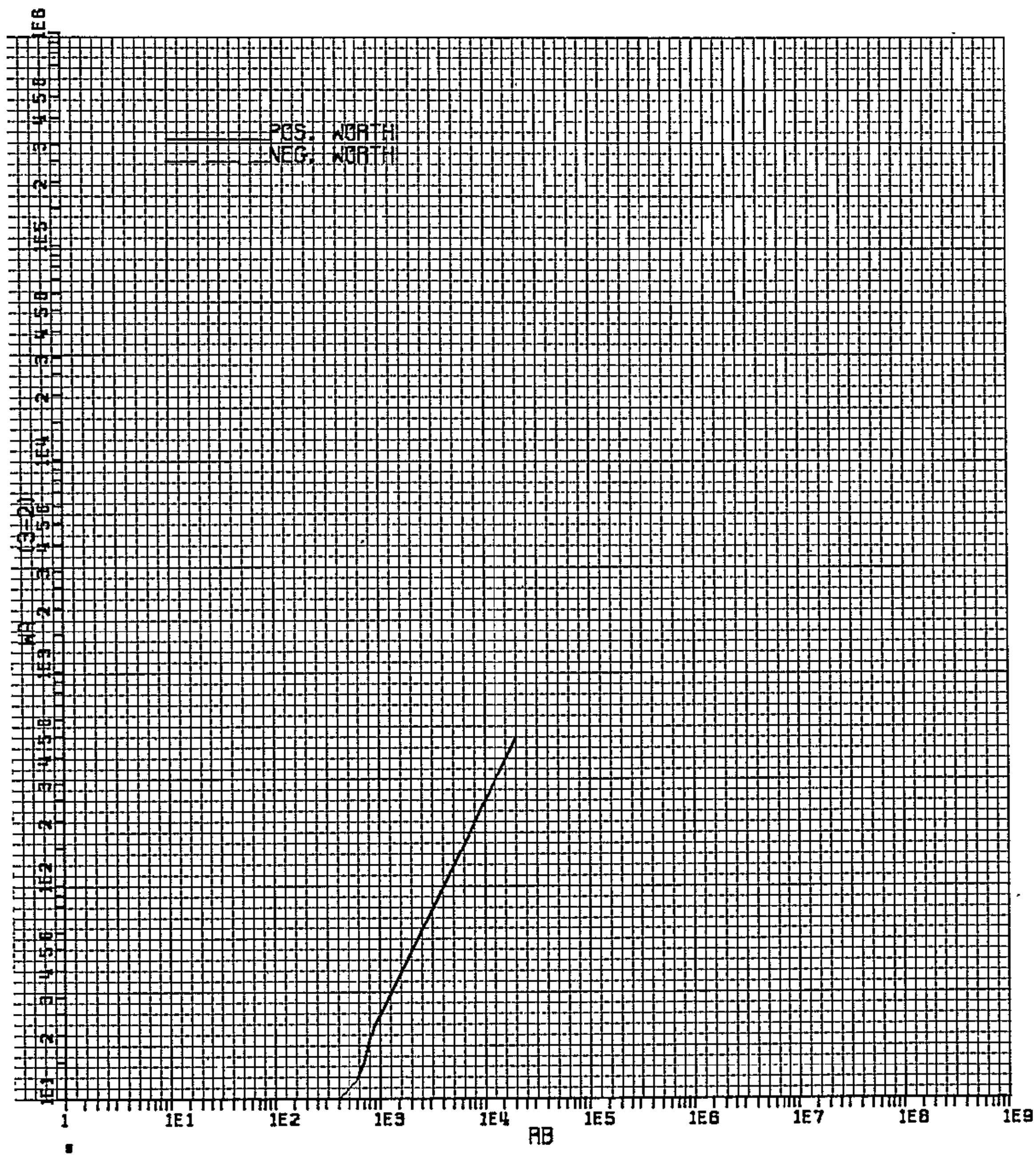
POS. WORTH
NEG. WORTH
WA (Z-1)
1E1
2
3
4
5
6
1E2
1E3
1E4
1E5
1E6
1
1E6
1E7
1E8
1E9
RB



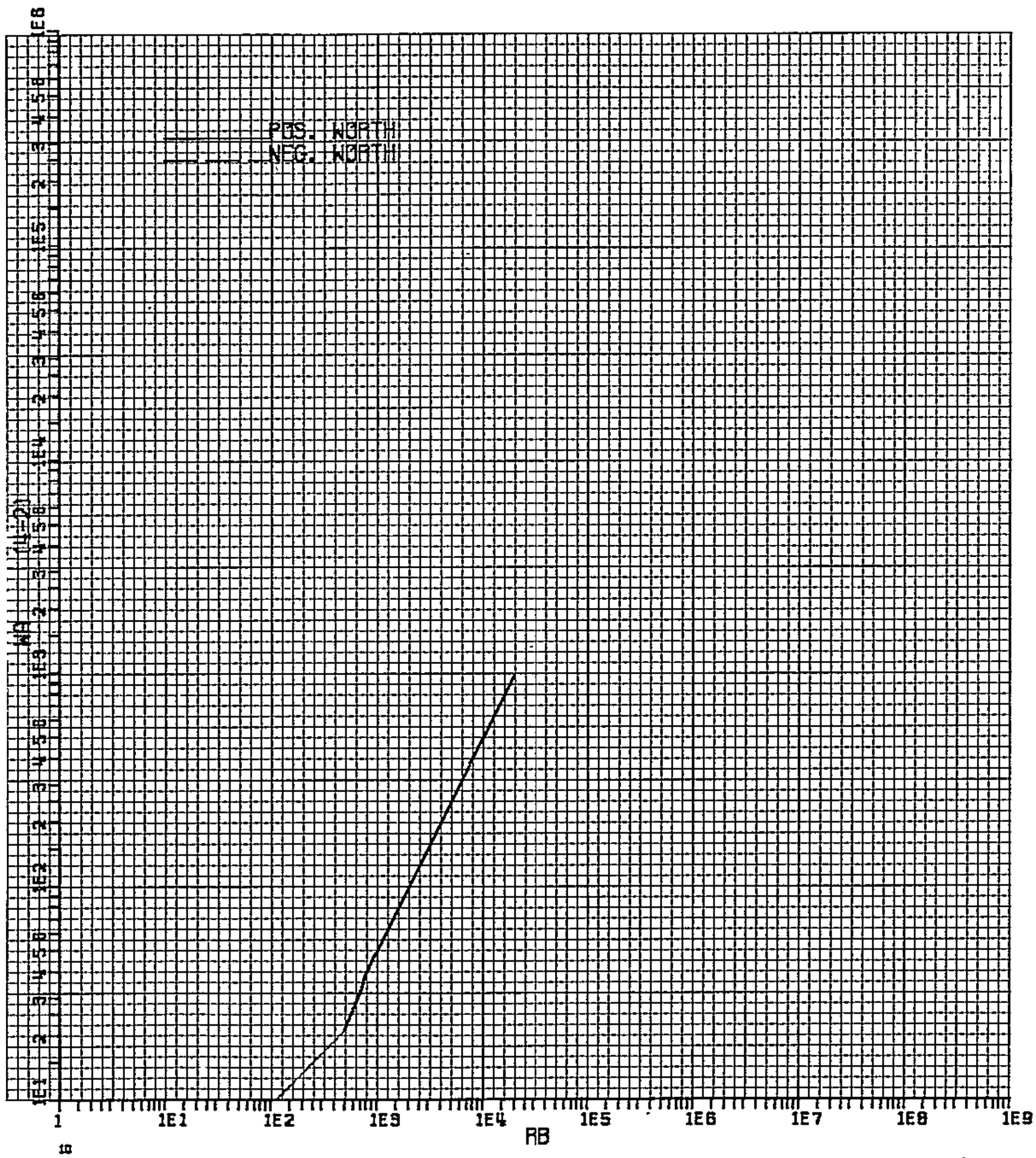
POS. WORTH
NEG. WORTH
WB (3-11)
1E1
2
3
4
5
6
1E2
1E3
1E4
1E5
1E6
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9
RB

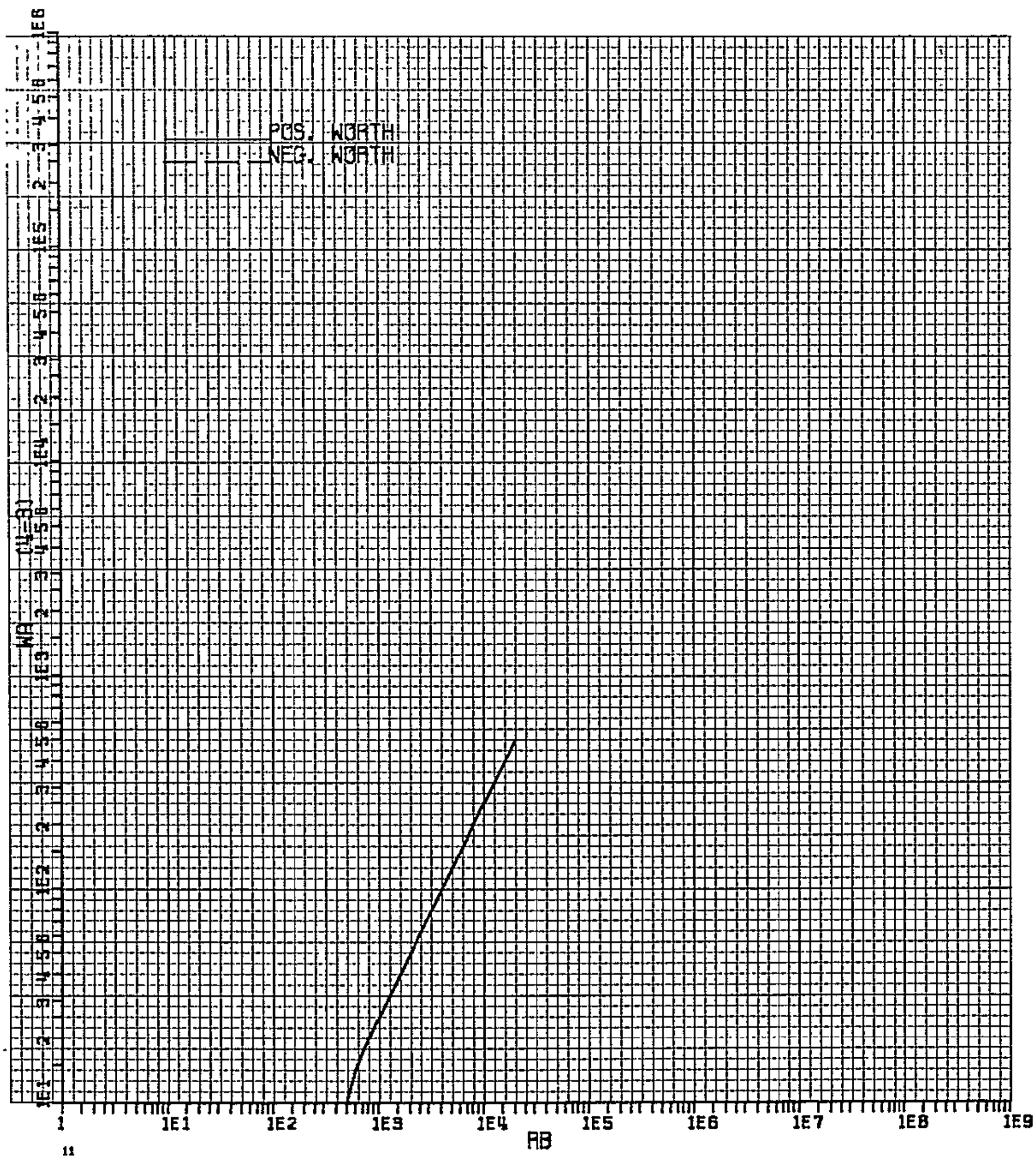


POS. WORTH
NEG. WORTH
WR (U=1)
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9



POS. WORTH
NEG. WORTH
WA (3-2)
AB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9


POS. WORTH
NEG. WORTH
WD (L=2)
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9



POS. WORTH
NEG. WORTH
WA (W=3)
RB
1
1E1
1E2
1E3
1E4
1E5
1E6
1E7
1E8
1E9

4.5 Library of Nominal System Burdens Data for COPTRAN

The following pages contain listings of the nominal System Burdens Data used in the COPTRAN program. (See Table IV-I, instruction No. 9.) Each of those detailed listings is summarized by a single COPTRAN instruction mnemonic.

4.5.1 Assigned Nominal System Burden Mnemonics

NXANTA XMTR ANT BURDENS, 0.51, SPACECRAFT

KTHT	14.		CONSTANT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
KDT	1.	E-02	CONSTANT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER
CKT	20.	E+03	XMTR ANT FAB COST INDEPENDENT OF XMTR ANT DIAMETER
WKT	25.		XMTR ANT WEIGHT INDEPENDENT OF XMTR ANT DIAMETER
MT	2.		EXPONENT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
NT	2.		EXPONENT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER

NXANTC XMTR ANT BURDENS, 0.84, SPACECRAFT

KTHT	14.		CONSTANT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
KDT	1.	E-02	CONSTANT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER
CKT	20.	E+03	XMTR ANT FAB COST INDEPENDENT OF XMTR ANT DIAMETER
WKT	25.		XMTR ANT WEIGHT INDEPENDENT OF XMTR ANT DIAMETER
MT	2.		EXPONENT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
NT	2.		EXPONENT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER

NXANTD XMTR ANT BURDENS, 10.6, SPACECRAFT

KTHT	14.		CONSTANT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
KDT	1.	E-02	CONSTANT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER
CKT	20.	E+03	XMTR ANT FAB COST INDEPENDENT OF XMTR ANT DIAMETER
WKT	25.		XMTR ANT WEIGHT INDEPENDENT OF XMTR ANT DIAMETER
MT	2.		EXPONENT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
NT	2.		EXPONENT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER

NXANTF XMTR ANT BURDENS,13CM,DIAMETER BURDENS,SPACECRAFT

KTHT	16.7		CONSTANT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
KDT	4.32	E-04	CONSTANT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER
CKT	5.	E+03	XMTR ANT FAB COST INDEPENDENT OF XMTR ANT DIAMETER
WKT	0.		XMTR ANT WEIGHT INDEPENDENT OF XMTR ANT DIAMETER
MT	2.		EXPONENT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
NT	2.		EXPONENT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER

NXANTG XMTR ANT BURDENS,13CM,GAIN BURDENS,SPACECRAFT

KTHT	5.2	E+02	CONSTANT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
KDT	1.35	E-02	CONSTANT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER
CKT	5.	E+03	XMTR ANT FAB COST INDEPENDENT OF XMTR ANT DIAMETER
WKT	0.		XMTR ANT WEIGHT INDEPENDENT OF XMTR ANT DIAMETER
MT	1.		EXPONENT RELATING XMTR ANT FAB COST TO XMTR ANT DIAMETER
NT	1.		EXPONENT RELATING XMTR ANT WEIGHT TO XMTR ANT DIAMETER

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NRANTA                     RCVR ANT BURDENS, 0.51, OPT DIRECT DETECTION, EARTH

KTHR      8.75             CONSTANT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
KDR        .023            CONSTANT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
CKR      25.      E+03     RCVR ANT FAB COST INDEPENDENT OF RCVR ANT DIAMETER
WKR      20.               RCVR ANT WEIGHT INDEPENDENT OF RCVR ANT DIAMETER
MR        2.               EXPONENT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
NR        2.               EXPONENT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER

NRANTB                     RCVR ANT BURDENS, 0.51, OPT HET OR HOM DETECTION, EARTH

KTHR      8.75             CONSTANT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
KDR        .023            CONSTANT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
CKR      25.      E+03     RCVR ANT FAB COST INDEPENDENT OF RCVR ANT DIAMETER
WKR      20.               RCVR ANT WEIGHT INDEPENDENT OF RCVR ANT DIAMETER
MR        2.               EXPONENT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
NR        2.               EXPONENT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER

NRANTC                     RCVR ANT BURDENS, 0.84, OPT DIRECT DETECTION, EARTH

KTHR      8.75             CONSTANT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
KDR        .023            CONSTANT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
CKR      25.      E+03     RCVR ANT FAB COST INDEPENDENT OF RCVR ANT DIAMETER
WKR      20.               RCVR ANT WEIGHT INDEPENDENT OF RCVR ANT DIAMETER
MR        2.               EXPONENT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
NR        2.               EXPONENT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER

NRANTD                     RCVR ANT BURDENS, 10.6, OPT DIRECT DETECTION, EARTH

KTHR      8.75             CONSTANT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
KDR        .023            CONSTANT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
CKR      25.      E+03     RCVR ANT FAB COST INDEPENDENT OF RCVR ANT DIAMETER
WKR      20.               RCVR ANT WEIGHT INDEPENDENT OF RCVR ANT DIAMETER
MR        2.               EXPONENT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
NR        2.               EXPONENT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER

NRANTE                     RCVR ANT BURDENS, 10.6, OPT HET OR HOM DETECTION, EARTH

KTHR      8.75             CONSTANT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
KDR        .023            CONSTANT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
CKR      25.      E+03     RCVR ANT FAB COST INDEPENDENT OF RCVR ANT DIAMETER
WKR      20.               RCVR ANT WEIGHT INDEPENDENT OF RCVR ANT DIAMETER
MR        2.               EXPONENT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
NR        2.               EXPONENT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
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NRANTF			RCVR ANT BURDENS,13CM,DIAMETER BURDENS,EARTH
KTHR	6.4	E-04	CONSTANT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
KDR	.0		CONSTANT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
CKR	0.		RCVR ANT FAB COST INDEPENDENT OF RCVR ANT DIAMETER
WKR	.0		RCVR ANT WEIGHT INDEPENDENT OF RCVR ANT DIAMETER
MR	2.7		EXPONENT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
NR	.0.		EXPONENT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER

NRANTG			RCVR ANT BURDENS,13CM,GAIN BURDENS,EARTH
KTHR	6.6	E-02	CONSTANT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
KDR			CONSTANT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER
CKR			RCVR ANT FAB COST INDEPENDENT OF RCVR ANT DIAMETER
WKR			RCVR ANT WEIGHT INDEPENDENT OF RCVR ANT DIAMETER
MR	1.35		EXPONENT RELATING RCVR ANT FAB COST TO RCVR ANT DIAMETER
NR			EXPONENT RELATING RCVR ANT WEIGHT TO RCVR ANT DIAMETER

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NXACTA                   XMTR ACQ AND TRACK BURDENS,OPTICAL FREQUENCY,SPACECRAFT

KAT       .71  E+05      CONSTANT RELATING XMTR TRACK EQUIP FAB COST TO XMTR BEAM
KWAT      .46            CONSTANT RELATING XMTR TRACK EQUIP WEIGHT TO XMTR ANT WT
KPQT      .48            CONSTANT RELATING XMTR ACQ-TRACK EQUIP PWR REQ TO WEIGHT
CAT       .4   E+06      XMTR ACQ-TRACK EQUIP FAB COST INDEPENDENT OF XMTR BEAM
WBT      5.              XMTR ACQ-TRACK EQUIP WEIGHT INDEPENDENT OF XMTR BEAM
QT        .3             EXPONENT RELATING XMTR TRACK EQUIP FAB COST TO XMTR BEAM

NXACTB                   XMTR ACQ AND TRACK BURDENS,RADIO FREQUENCY,SPACE,DIAM

KAT       .71  E+05      CONSTANT RELATING XMTR TRACK EQUIP FAB COST TO XMTR BEAM
KWAT      .75            CONSTANT RELATING XMTR TRACK EQUIP WEIGHT TO XMTR ANT WT
KPQT    10.              CONSTANT RELATING XMTR ACQ-TRACK EQUIP PWR REQ TO WEIGHT
CAT       .14  E+06      XMTR ACQ-TRACK EQUIP FAB COST INDEPENDENT OF XMTR BEAM
WBT     10.              XMTR ACQ-TRACK EQUIP WEIGHT INDEPENDENT OF XMTR BEAM
QT        .3             EXPONENT RELATING XMTR TRACK EQUIP FAB COST TO XMTR BEAM

NXACTC                   XMTR ACQ AND TRACK BURDENS,RADIO FREQUENCY,SPACE,GAIN

KAT       .71  E+05      CONSTANT RELATING XMTR TRACK EQUIP FAB COST TO XMTR BEAM
KWAT      .75            CONSTANT RELATING XMTR TRACK EQUIP WEIGHT TO XMTR ANT WT
KPQT    10.              CONSTANT RELATING XMTR ACQ-TRACK EQUIP PWR REQ TO WEIGHT
CAT       .14  E+06      XMTR ACQ-TRACK EQUIP FAB COST INDEPENDENT OF XMTR BEAM
WBT     10.              XMTR ACQ-TRACK EQUIP WEIGHT INDEPENDENT OF XMTR BEAM
QT        .3             EXPONENT RELATING XMTR TRACK EQUIP FAB COST TO XMTR BEAM
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NRACTA RCVR ACQ AND TRACK BURDENS,OPTICAL FREQUENCY,EARTH

KAR	.71	E+05	CONSTANT RELATING RCVR TRACK EQUIP FAB COST TO RCVR BEAM
KWAR	.46		CONSTANT RELATING RCVR TRACK EQUIP WEIGHT TO RCVR ANT WT
KPQR	.48		CONSTANT RELATING XMTR ACQ-TRACK EQUIP PWR REQ TO WEIGHT
CAR	.2	E+06	RCVR ACQ-TRACK EQUIP FAB COST INDEPENDENT OF RCVR BEAM
WBR	5.0		RCVR ACQ-TRACK EQUIP WEIGHT INDEPENDENT OF RCVR BEAM
QR	.3		EXPONENT RELATING RCVR TRACK EQUIP FAB COST TO RCVR BEAM

NRACTB RCVR ACQ AND TRACK BURDENS,RADIO FREQUENCY,EARTH,DIAM

KAR	.0	CONSTANT RELATING RCVR TRACK EQUIP FAB COST TO RCVR BEAM
KWAR	.0	CONSTANT RELATING RCVR TRACK EQUIP WEIGHT TO RCVR ANT WT
KPQR	.0	CONSTANT RELATING XMTR ACQ-TRACK EQUIP PWR REQ TO WEIGHT
CAR	.0	RCVR ACQ-TRACK EQUIP FAB COST INDEPENDENT OF RCVR BEAM
WBR	.0	RCVR ACQ-TRACK EQUIP WEIGHT INDEPENDENT OF RCVR BEAM
QR	.0	EXPONENT RELATING RCVR TRACK EQUIP FAB COST TO RCVR BEAM

NRACTC RCVR ACQ AND TRACK BURDENS,RADIO FREQUENCY,EARTH,GAIN

KAR	.0	CONSTANT RELATING RCVR TRACK EQUIP FAB COST TO RCVR BEAM
KWAR	.0	CONSTANT RELATING RCVR TRACK EQUIP WEIGHT TO RCVR ANT WT
KPQR	.0	CONSTANT RELATING XMTR ACQ-TRACK EQUIP PWR REQ TO WEIGHT
CAR	.0	RCVR ACQ-TRACK EQUIP FAB COST INDEPENDENT OF RCVR BEAM
WBR	.0	RCVR ACQ-TRACK EQUIP WEIGHT INDEPENDENT OF RCVR BEAM
QR	.0	EXPONENT RELATING RCVR TRACK EQUIP FAB COST TO RCVR BEAM

NMODEA			MODULATION EQUIP BURDENS, 0.51, CW LASER, SPACECRAFT
KFM	7.5	E-05	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	5.	E-08	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	7.5	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	5.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODEB			MODULATION EQUIP BURDENS, 0.84, CW LASER, SPACECRAFT
KFM	7.5	E-05	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	5.	E-08	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	7.5	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	5.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODEC			MODULATION EQUIP BURDENS, 0.84, PULSED LASER, SPACECRAFT
KFM	.5	E-03	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	.3	E-06	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	15.	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	10.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODED			MODULATION EQUIP BURDENS, 10.6, CW LASER, SPACECRAFT
KFM	.5	E-03	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	.3	E-06	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	15.	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	10.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODEE			MODULATION EQUIP BURDENS, 13CM, SPACECRAFT
KFM	.0		CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	.0		CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	.0		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	.0		MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	.0		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE

NMODEF			MODULATION EQUIP BURDENS, 0.51, CW LASER, EARTH
KFM	7.5	E-05	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	5.	E-08	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	7.5	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	5.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODEG			MODULATION EQUIP BURDENS, 0.84, CW LASER, EARTH
KFM	7.5	E-05	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	5.	E-08	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	7.5	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	5.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODEH			MODULATION EQUIP BURDENS, 0.84, PULSED LASER, EARTH
KFM	.5	E-03	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	.3	E-06	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	15.	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	10.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODEI			MODULATION EQUIP BURDENS, 10.6, CW LASER, EARTH
KFM	.5	E-03	CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	.3	E-06	CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	5.		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	15.	E+03	MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	10.		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NMODEJ			MODULATION EQUIP BURDENS, 13CM, EARTH
KFM	.0		CONSTANT RELATING MOD EQUIP FAB COST TO INFORMATION RATE
KM	.0		CONSTANT RELATING MOD EQUIP WEIGHT TO INFORMATION RATE
KPM	.0		CONSTANT RELATING MOD EQUIP PWR REQ TO EQUIP WEIGHT
CKM	.0		MOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKM	.0		MOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE

NDMODA			DEMODULATION EQUIP BURDENS, OPTICAL DIR DET, EARTH
KFD	5.5	E-05	CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	1.1	E-07	CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	3.33		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	15.	E+03	DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	30.		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NDMOBB			DEMODULATION EQUIP BURDENS, OPTICAL HET DET, EARTH
KFD	.1	E-03	CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	.2	E-06	CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	3.33		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	27.5	E+03	DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	55.		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NDMOBC			DEMODULATION EQUIPMENT BURDENS, OPTICAL HOM DET, EARTH
KFD	.1	E-03	CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	.2	E-06	CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	3.33		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	27.5	E+03	DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	55.		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NDMOBE			DEMODULATION EQUIPMENT BURDENS, 13CM RADIO HOM DET,EARTH
KFD	.0		CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	.0		CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	.0		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	.0		DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	.0		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE
NDMOBF			DEMODULATION EQUIPMENT BURDENS, OPTICAL DIRECT DET,SPACE
KFD	5.5	E-05	CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	1.1	E-07	CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	3.33		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	15.	E+03	DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	30.		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE

NDMODG DEMODULATION EQUIPMENT BURDENS, OPTICAL HET DET, SPACE

KFD	.1	E-03	CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	.2	E-06	CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	3.33		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	27.5	E+03	DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	55.		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE

NDMODH DEMODULATION EQUIPMENT BURDENS, OPTICAL HOM DET, SPACE

KFD	.1	E-03	CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	.2	E-06	CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	3.33		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	27.5	E+03	DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	55.		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE

NDMODI DEMODULATION EQUIPMENT BURDENS, 13CM RADIO DIR DET,SPACE

KFD	.0		CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	.0		CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	.0		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	.0		DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	.0		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE

NDMODJ DEMODULATION EQUIPMENT BURDENS, 13CM RADIO HOM DET,SPACE

KFD	.0		CONSTANT RELATING DEMOD EQUIP FAB COST TO INFO RATE
KD	.0		CONSTANT RELATING DEMOD EQUIP WEIGHT TO INFORMATION RATE
KPD	.0		CONSTANT RELATING DEMOD EQUIP PWR REQ TO EQUIP WEIGHT
CKD	.0		DEMOD EQUIP FAB COST INDEPENDENT OF INFORMATION RATE
WKD	.0		DEMOD EQUIP WEIGHT INDEPENDENT OF INFORMATION RATE

NXPWSA			XMTR POWER SUPPLY BURDENS,RTG,SPACECRAFT
KST	3.	E+03	CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
KWST	.7		CONSTANT RELATING XMTR PWR SUPPLY WEIGHT TO PWR REQ.
CKE	0.		XMTR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKE	0.		XMTR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ
NXPWSB			XMTR POWER SUPPLY BURDENS,REACTOR,SPACECRAFT
KST	5.	E+02	CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
KWST	.625		CONSTANT RELATING XMTR PWR SUPPLY WEIGHT TO PWR REQ
CKE	1.2	E+06	XMTR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKE	400.		XMTR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ
NXPWSC			XMTR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,MARS
KST	112.		CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
KWST	.11		CONSTANT RELATING XMTR PWR SUPPLY WEIGHT TO PWR REQ
CKE	0.		XMTR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKE	0.		XMTR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ
NXPWSD			XMTR POWER SUPPLY BURDENS,GENERATOR,EARTH
KST	25.		CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
KWST	.0		CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
CKE	10.	E+03	XMTR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKE	.0		XMTR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ
NXPWSE			XMTR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,SAT
KST	166.		CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
KWST	.157		CONSTANT RELATING XMTR PWR SUPPLY WEIGHT TO PWR REQ
CKE	0.		XMTR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKE	0.		XMTR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ
NXPWSF			XMTR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,VENUS
KST	38.		CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
KWST	.04		CONSTANT RELATING XMTR PWR SUPPLY WEIGHT TO PWR REQ
CKE	0.		XMTR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKE	0.		XMTR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

NXPWSG		XMTR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,MERCURY
KST	43.	CONSTANT RELATING XMTR PWR SUPPLY FAB COST TO PWR REQ
KWST	.04	CONSTANT RELATING XMTR PWR SUPPLY WEIGHT TO PWR REQ
CKE	0.	XMTR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKE	0.	XMTR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

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NRPWSA                      RCVR POWER SUPPLY BURDENS,RTG,SPACECRAFT

KSR         3.     E+03  CONSTANT RELATING RCVR PWR SUPPLY FAB COST TO PWR REQ
KWSR         .7          CONSTANT RELATING RCVR PWR SUPPLY WEIGHT TO PWR REQ.
CKF         0.           RCVR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKF         0.           RCVR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

NRPWSB                      RCVR POWER SUPPLY BURDENS,REACTOR,SPACECRAFT

KSR         5.     E+02  CONSTANT RELATING RCVR PWR SUPPLY FAB COST TO PWR REQ
KWSR         .625        CONSTANT RELATING RCVR PWR SUPPLY WEIGHT TO PWR REQ.
CKF         1.2    E+06  RCVR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKF       400.           RCVR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

NRPWSC                      RCVR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,MARS

KSR       112.           CONSTANT RELATING RCVR PWR SUPPLY FAB COST TO PWR REQ
KWSR         .11         CONSTANT RELATING RCVR PWR SUPPLY WEIGHT TO PWR REQ.
CKF         0.           RCVR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKF         0.           RCVR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

NRPWSD                      RCVR POWER SUPPLY BURDENS,GENERATOR,EARTH

KSR        25.           CONSTANT RELATING RCVR PWR SUPPLY FAB COST TO PWR REQ
KWSR                     CONSTANT RELATING RCVR PWR SUPPLY WEIGHT TO PWR REQ.
CKF        10.     E+03  RCVR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKF                      RCVR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

NRPWSE                      RCVR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,SAT

KSR       166.           CONSTANT RELATING RCVR PWR SUPPLY FAB COST TO PWR REQ
KWSR         .137        CONSTANT RELATING RCVR PWR SUPPLY WEIGHT TO PWR REQ.
CKF         0.           RCVR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKF         0.           RCVR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

NRPWSF                      RCVR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,VENUS

KSR        38.           CONSTANT RELATING RCVR PWR SUPPLY FAB COST TO PWR REQ
KWSR         .04         CONSTANT RELATING RCVR PWR SUPPLY WEIGHT TO PWR REQ.
CKF         0.           RCVR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKF         0.           RCVR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ
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NRPWSG		RCVR POWER SUPPLY BURDENS,SOLAR CELL,SPACECRAFT,MERCURY
KSR.	43.	CONSTANT RELATING RCVR PWR SUPPLY FAB COST TO PWR REQ
KWSR	.04	CONSTANT RELATING RCVR PWR SUPPLY WEIGHT TO PWR REQ.
CKF	0.	RCVR PWR SUPPLY FAB COST INDEPENDENT OF PWR REQ
WKF	0.	RCVR PWR SUPPLY WEIGHT INDEPENDENT OF PWR REQ

NXMTRA			XMTR BURDENS,0.51 ,SPACECRAFT
KPT	150.		CONSTANT RELATING XMTR FAB COST TO XMTR PWR
KWT	51.		CONSTANT RELATING XMTR WEIGHT TO XMTR PWR
KH	.58		CONSTANT RELATING XMTR HEAT EX FAB COST TO XMTR PWR DIS
KX	.7	E-02	CONSTANT RELATING XMTR HEAT EX WEIGHT TO XMTR PWP DIS
KE	.001		XMTR PWR EFFICIENCY
CKP	3.5	E+03	XMTR FAB COST INDEPENDENT OF XMTR PWR
CKH	13.8	E+03	XMTR HEAT EX FAB COST INDEPENDENT OF XMTR PWR
WKP	40.		XMTR WEIGHT INDEPENDENT OF XMTR PWR
WKH	0.		XMTR HEAT EX WEIGHT INDEPENDENT OF XMTR PWR
GT	1.		EXPONENT RELATING XMTR FAB COST TO XMTR PWR
HT	1.		EXPONENT RELATING XMTR WEIGHT TO XMTR PWR
JT	1.		EXPONENT RELATING XMTR PWR SUP-HEAT EX BURD TO XMTR PWR

NXMTRB			XMTR BURDENS,0.51 ,EARTH
KPT	150.		CONSTANT RELATING XMTR FAB COST TO XMTR PWR
KWT	51.		CONSTANT RELATING XMTR WEIGHT TO XMTR PWR
KH	0.		CONSTANT RELATING XMTR HEAT EX FAB COST TO XMTR PWR DIS
KX	0.		CONSTANT RELATING XMTR HEAT EX WEIGHT TO XMTR PWP DIS
KE	.001		XMTR PWR EFFICIENCY
CKP	3.5	E+03	XMTR FAB COST INDEPENDENT OF XMTR PWR
CKH	0.		XMTR HEAT EX FAB COST INDEPENDENT OF XMTR PWR
WKP	40.		XMTR WEIGHT INDEPENDENT OF XMTR PWR
WKH	0.		XMTR HEAT EX WEIGHT INDEPENDENT OF XMTR PWR
GT	1.		EXPONENT RELATING XMTR FAB COST TO XMTR PWR
HT	1.		EXPONENT RELATING XMTR WEIGHT TO XMTR PWR
JT	1.		EXPONENT RELATING XMTR PWR SUP-HEAT EX BURD TO XMTR PWR

NXMTRE			XMTR BURDENS,10.6 ,SPACECRAFT
KPT	1.43		CONSTANT RELATING XMTR FAB COST TO XMTR PWR
KWT	2.		CONSTANT RELATING XMTR WEIGHT TO XMTR PWR
KH	1.97		CONSTANT RELATING XMTR HEAT EX FAB COST TO XMTR PWR DIS
KX	2.5	E-02	CONSTANT RELATING XMTR HEAT EX WEIGHT TO XMTR PWP DIS
KE	.1		XMTR PWR EFFICIENCY
CKP	2.	E+03	XMTR FAB COST INDEPENDENT OF XMTR PWR
CKH	13.8	E+03	XMTR HEAT EX FAB COST INDEPENDENT OF XMTR PWR
WKP	25.		XMTR WEIGHT INDEPENDENT OF XMTR PWR
WKH	0.		XMTR HEAT EX WEIGHT INDEPENDENT OF XMTR PWR
GT	1.		EXPONENT RELATING XMTR FAB COST TO XMTR PWR
HT	1.		EXPONENT RELATING XMTR WEIGHT TO XMTR PWR
JT	1.		EXPONENT RELATING XMTR PWR SUP-HEAT EX BURD TO XMTR PWR

NXMTRF XMTR BURDENS, 10.6, EARTH

KPT	1.43		CONSTANT RELATING XMTR FAB COST TO XMTR PWR
KWT	2.		CONSTANT RELATING XMTR WEIGHT TO XMTR PWR
KH	0.		CONSTANT RELATING XMTR HEAT EX FAB COST TO XMTR PWR DIS
KX	0.		CONSTANT RELATING XMTR HEAT EX WEIGHT TO XMTR PWP DIS
KE	.1		XMTR PWR EFFICIENCY
CKP	2.	E+03	XMTR FAB COST INDEPENDENT OF XMTR PWR
CKH	0.		XMTR HEAT EX FAB COST INDEPENDENT OF XMTR PWR
WKP	25.		XMTR WEIGHT INDEPENDENT OF XMTR PWR
WKH	0.		XMTR HEAT EX WEIGHT INDEPENDENT OF XMTR PWR
GT	1.		EXPONENT RELATING XMTR FAB COST TO XMTR PWR
HT	1.		EXPONENT RELATING XMTR WEIGHT TO XMTR PWR
JT	1.		EXPONENT RELATING XMTR PWR SUP-HEAT EX BURD TO XMTR PWR

NXMTRG XMTR BURDENS, 13CM, SPACECRAFT

KPT	120.		CONSTANT RELATING XMTR FAB COST TO XMTR PWR
KWT	.1		CONSTANT RELATING XMTR WEIGHT TO XMTR PWR
KH	.58		CONSTANT RELATING XMTR HEAT EX FAB COST TO XMTR PWR DIS
KX	.7	E-02	CONSTANT RELATING XMTR HEAT EX WEIGHT TO XMTR PWP DIS
KE	.25		XMTR PWR EFFICIENCY
CKP	17.5	E+03	XMTR FAB COST INDEPENDENT OF XMTR PWR
CKH	13.8	E+03	XMTR HEAT EX FAB COST INDEPENDENT OF XMTR PWR
WKP	5.		XMTR WEIGHT INDEPENDENT OF XMTR PWR
WKH	0.		XMTR HEAT EX WEIGHT INDEPENDENT OF XMTR PWR
GT	1.		EXPONENT RELATING XMTR FAB COST TO XMTR PWR
HT	1.		EXPONENT RELATING XMTR WEIGHT TO XMTR PWR
JT	1.		EXPONENT RELATING XMTR PWR SUP-HEAT EX BURD TO XMTR PWR

NXMTRH XMTR BURDENS, 13CM, EARTH

KPT	120.		CONSTANT RELATING XMTR FAB COST TO XMTR PWR
KWT	.1		CONSTANT RELATING XMTR WEIGHT TO XMTR PWR
KH	0.		CONSTANT RELATING XMTR HEAT EX FAB COST TO XMTR PWR DIS
KX	0.		CONSTANT RELATING XMTR HEAT EX WEIGHT TO XMTR PWP DIS
KE	.25		XMTR PWR EFFICIENCY
CKP	17.5	E+03	XMTR FAB COST INDEPENDENT OF XMTR PWR
CKH	0.		XMTR HEAT EX FAB COST INDEPENDENT OF XMTR PWR
WKP	5.		XMTR WEIGHT INDEPENDENT OF XMTR PWR
WKH	0.		XMTR HEAT EX WEIGHT INDEPENDENT OF XMTR PWR
GT	1.		EXPONENT RELATING XMTR FAB COST TO XMTR PWR
HT	1.		EXPONENT RELATING XMTR WEIGHT TO XMTR PWR
JT	1.		EXPONENT RELATING XMTR PWR SUP-HEAT EX BURD TO XMTR PWR

4.5.2 Complete listing of COPTRAN burden memories.

		IMPLEMENTED
NXANTA	XMTR ANT BURDENS, 0.51, SPACECRAFT	YES
NXANTB	XMTR ANT BURDENS (EXTRA)	NO
NXANTC	XMTR ANT BURDENS, 0.84, SPACECRAFT	YES
NXANTD	XMTR ANT BURDENS, 10.6, SPACECRAFT	YES
NXANTE	XMTR ANT BURDENS, 10.6, HETERODYNE DETECTION, SPACECRAFT	YES
NXANTF	XMTR ANT BURDENS, 13CM, DIAMETER BURDENS, SPACECRAFT	YES
NXANTG	XMTR ANT BURDENS, 13CM, GAIN BURDENS, SPACECRAFT	YES
NXANTH	XMTR ANT BURDENS, (EXTRA)	NO
NXANTI	XMTR ANT BURDENS, (EXTRA)	NO
NXANTJ	XMTR ANT BURDENS, (EXTRA)	NO
NXANTK	XMTR ANT BURDENS, (EXTRA)	NO
NXANTL	XMTR ANT BURDENS, (EXTRA)	NO
NXANTM	XMTR ANT BURDENS, (EXTRA)	NO
NXANTN	XMTR ANT BURDENS, (EXTRA)	NO
NXANTO	XMTR ANT BURDENS, (EXTRA)	NO
NXANTP	XMTR ANT BURDENS, (EXTRA)	NO
NXANTQ	XMTR ANT BURDENS, (EXTRA)	NO
NXANTR	XMTR ANT BURDENS, (EXTRA)	NO
NXANTS	XMTR ANT BURDENS, (EXTRA)	NO
NXANTT	XMTR ANT BURDENS, (EXTRA)	NO
NRANTA	RCVR ANT BURDENS, 0.51, OPT DIRECT DETECTION, EARTH	YES
NRANTB	RCVR ANT BURDENS, 0.51, OPT HET OR HOM DET, EARTH	YES
NRANTC	RCVR ANT BURDENS, 0.84, OPT DIRECT DETECTION, EARTH	YES
NRANTD	RCVR ANT BURDENS, 10.6, OPT DIRECT DETECTION, EARTH	YES
NRANTE	RCVR ANT BURDENS, 10.6, OPT HET OR HOM DET, EARTH	YES
NRANTF	RCVR ANT BURDENS, 13CM, DIAMETER BURDENS, EARTH	YES
NRANTG	RCVR ANT BURDENS, 13CM, GAIN BURDENS, EARTH	YES
NRANTH	RCVR ANT BURDENS, (EXTRA)	NO
NRANTI	RCVR ANT BURDENS, (EXTRA)	NO
NRANTJ	RCVR ANT BURDENS, (EXTRA)	NO
NRANTK	RCVR ANT BURDENS, (EXTRA)	NO
NRANTL	RCVR ANT BURDENS, (EXTRA)	NO
NRANTM	RCVR ANT BURDENS, (EXTRA)	NO
NRANTN	RCVR ANT BURDENS, (EXTRA)	NO
NRANTO	RCVR ANT BURDENS, (EXTRA)	NO
NRANTP	RCVR ANT BURDENS, (EXTRA)	NO

		IMPLEMENTED
NRANTQ	RCVR ANT BURDENS, (EXTRA)	NO
NRANTR	RCVR ANT BURDENS, (EXTRA)	NO
NRANTS	RCVR ANT BURDENS, (EXTRA)	NO
NRANTT	RCVR ANT BURDENS, (EXTRA)	NO
NXACTA	XMTR ACQ AND TRACK BURDENS, OPTICAL FREQUENCY, SPACECRAFT	YES
NXACTB	XMTR ACQ AND TRACK BURDENS, RADIO FREQUENCY, SPACE, DIAM	YES
NXACTC	XMTR ACQ AND TRACK BURDENS, RADIO FREQUENCY, SPACE, GAIN	YES
NXACTD	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTE	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTF	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTG	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTH	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTI	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTJ	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTK	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTL	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTM	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTN	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTO	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTP	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTQ	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTR	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTS	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NXACTT	XMTR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTA	RCVR ACQ AND TRACK BURDENS, OPTICAL FREQUENCY, EARTH	YES
NRACTB	RCVR ACQ AND TRACK BURDENS, RADIO FREQUENCY, EARTH, DIAM	YES
NRACTC	RCVR ACQ AND TRACK BURDENS, RADIO FREQUENCY, EARTH, GAIN	YES
NRACTD	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTE	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTF	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTG	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTH	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTI	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTJ	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTK	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTL	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTM	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO

		IMPLEMENTED
NRACTN	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTO	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTP	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTQ	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTR	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTS	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NRACTT	RCVR ACQ AND TRACK BURDENS, (EXTRA)	NO
NMODEA	MODULATION EQUIP BURDENS, 0.51, CW LASER, SPACECRAFT	YES
NMODEB	MODULATION EQUIP BURDENS, 0.84, CW LASER, SPACECRAFT	YES
NMODEC	MODULATION EQUIP BURDENS, 0.84, PULSED LASER, SPACECRAFT	YES
NMODED	MODULATION EQUIP BURDENS, 10.6, CW LASER,SPACECRAFT	YES
NMODEE	MODULATION EQUIP BURDENS, 13CM, SPACECRAFT	YES
NMODEF	MODULATION EQUIP BURDENS, 0.51, CW LASER, EARTH	YES
NMODEG	MODULATION EQUIP BURDENS, 0.84, CW LASER, EARTH	YES
NMODEH	MODULATION EQUIP BURDENS, 0.89, PULSED LASER, EARTH	YES
NMODEI	MODULATION EQUIP BURDENS, 10.6, CW LASER, EARTH	YES
NMODEJ	MODULATION EQUIP BURDENS, 13CM, EARTH	YES
NMODEK	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODEL	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODEM	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODEN	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODEO	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODEP	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODEQ	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODER	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODES	MODULATION EQUIP BURDENS, (EXTRA)	NO
NMODET	MODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODA	DEMODULATION EQUIPMENT BURDENS, OPTICAL DIR DET, EARTH	YES
NDMODB	DEMODULATION EQUIPMENT BURDENS, OPTICAL HET DET, EARTH	YES
NDMODC	DEMODULATION EQUIPMENT BURDENS, OPTICAL HOM DET, EARTH	YES
NDMODD	DEMODULATION EQUIPMENT BURDENS, (EXTRA)	NO
NDMODE	DEMODULATION EQUIPMENT BURDENS, 13CM RADIO, HOM DET, EARTH	YES
NDMODF	DEMODULATION EQUIPMENT BURDENS, OPTICAL DIRECT DET, SPACE	YES
NDMODG	DEMODULATION EQUIPMENT BURDENS, OPTICAL HET DET, SPACE	YES
NDMODH	DEMODULATION EQUIPMENT BURDENS, OPTICAL HOM DET, SPACE	YES
NDMODI	DEMODULATION EQUIPMENT BURDENS, 13CM RADIO, DIR DET, SPACE	YES
NDMODJ	DEMODULATION EQUIPMENT BURDENS, 13CM RADIO, HOM DET, SPACE	YES

		IMPLEMENTED
NDMODK	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODL	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODM	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODN	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODO	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODP	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODQ	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODR	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODS	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NDMODT	DEMODULATION EQUIP BURDENS, (EXTRA)	NO
NXPWSA	XMTR POWER SUPPLY BURDENS, RTG, SPACECRAFT	YES
NXPWSB	XMTR POWER SUPPLY BURDENS, REACTOR, SPACECRAFT	YES
NXPWSC	XMTR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, MARS	YES
NXPWSD	XMTR POWER SUPPLY BURDENS, GENERATOR, EARTH	YES
NXPWSE	XMTR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, SAT	YES
NXPWSF	XMTR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, VENUS	YES
NXPWSG	XMTR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, MERCURY	YES
NXPWSH	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSI	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSJ	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSK	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSL	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSM	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSN	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSO	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSP	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSQ	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSR	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWSS	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NXPWST	XMTR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSA	RCVR POWER SUPPLY BURDENS, RTG, SPACECRAFT	YES
NRPWSB	RCVR POWER SUPPLY BURDENS, REACTOR, SPACECRAFT	YES
NRPWSC	RCVR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, MARS	YES
NRPWSD	RCVR POWER SUPPLY BURDENS, GENERATOR, EARTH	YES
NRPWSE	RCVR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, SAT	YES
NRPWSF	RCVR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, VENUS	YES
NRPWSG	RCVR POWER SUPPLY BURDENS, SOLAR CELL, SPACECRAFT, MERCURY	YES

		IMPLEMENTED
NRPWSH	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSI	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSJ	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSK	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSL	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSM	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSN	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSO	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSP	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSQ	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSR	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWSS	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NRPWST	RCVR POWER SUPPLY BURDENS, (EXTRA)	NO
NXMTRA	XMTR BURDENS, 0.51, SPACECRAFT	YES
NXMTRB	XMTR BURDENS, 0.51, EARTH	YES
NXMTRC	XMTR BURDENS, (EXTRA)	NO
NXMTRD	XMTR BURDENS, 0.84, (EXTRA)	NO
NXMTRE	XMTR BURDENS, 10.6, SPACECRAFT	YES
NXMTRF	XMTR BURDENS, 10.6, EARTH	YES
NXMTRG	XMTR BURDENS, 13CM, SPACECRAFT	YES
NXMTRH	XMTR BURDENS, 13CM, EARTH	YES
NXMTRI	XMTR BURDENS, (EXTRA)	NO
NXMTRJ	XMTR BURDENS, (EXTRA)	NO
NXMTRK	XMTR BURDENS, (EXTRA)	NO
NXMTRL	XMTR BURDENS, (EXTRA)	NO
NXMTRM	XMTR BURDENS, (EXTRA)	NO
NXMTRN	XMTR BURDENS, (EXTRA)	NO
NXMTRO	XMTR BURDENS, (EXTRA)	NO
NXMTRP	XMTR BURDENS, (EXTRA)	NO
NXMTRQ	XMTR BURDENS, (EXTRA)	NO
NXMTRR	XMTR BURDENS, (EXTRA)	NO
NXMTRS	XMTR BURDENS, (EXTRA)	NO
NXMTRT	XMTR BURDENS, (EXTRA)	NO

4.5.3 MNEMONIC assignment procedure. — In order to supply values for those burdens sets for which no values presently exist (See 4.5.2), the following procedure should be followed using as an example an unassigned burden Mnemonic, NXANTE.

1. Select that set for which no values are presently supplied, e.g., NXANTE
2. In the nominal value data deck, locate the data values associated with the NXANT — (transmitter antenna) burdens set.
3. Locate the specific set associated with the particular burdens set desired. In this case, E is the set desired. Since, in the transmitter antenna burdens there are six values for each set, the E set is the fifth set, or the 26th, 27th, 28th, 29th and 30th data values. The location in the table is given by

$$N_1, N_2, \ldots, N_m = k \cdot (m-1) + 1,\ k \cdot (m-1) + 2, \ldots, k \cdot m$$

where

k corresponds to the burden set desired $A \Rightarrow 1$, $B \Rightarrow 2$, . . . , etc.

m is the number of values per set.

4. Add the values desired into the burden set located in 3. above.

In this way, burdens values may be added or altered as desired.

4.6 Automatic COPTRAN Burden Data Selection Logic

Automatic burden data selection by the COPTRAN program is made according to the selection tables in the following sections. This selection will always be made unless other specific instructions or data are included. In such a case, the specific instructions or data over-ride the automatic selection logic.

4.6.1 Nominal Systems Burdens Selection Logic

TRANSMITTER ANTENNA

	0.51 μ	0.84 μ	10.6 μ	13 cm Diameter Burdens	13 cm Gain Burdens
Spacecraft Transmitter	NXANTA	NXANTC	NXANTD	NXANTF	NXANTG

RECEIVER ANTENNA

		0.51μ	0.84μ	10.6μ	13 cm Diameter Burdens	13 cm Gain Burdens
Earth Receiver	Direct Detection	NRANTA	NRANTC	NRANTD	NRANTF	NRANTG
	Het. or Hom. Detection	NRANTB	X	NRANTE		

X - Forbidden combination

TRANSMITTER ACQUISITION
AND TRACK SYSTEM

	Optical Frequency	Radio Freq. Diam. Burdens	Radio Freq. Gain Burdens
Spacecraft Transmitter	NXACTA	NXACTB	NXACTC

RECEIVER ACQUISITION
AND TRACK SYSTEM

	Optical Frequency	Radio Freq. Diam. Burdens	Radio Freq. Gain Burdens
Earth Receiver	NRACTA	NRACTB	NRACTC

MODULATION
EQUIPMENT - SPACE

	0.51μ	0.84μ	10.6μ	13 cm
PCM/AM	NMODEA	NMODEB	NMODED	NMODEE
PCM/PL	NMODEA	NMODEB	NMODED	X
PCM/FM	NMODEA	NMODEB	NMODED	NMODEE
PCM/PM	NMODEA	NMODEB	NMODED	NOMDEE
PPM/AM	NMODEA	NMODEC	NMODED	X

X - Forbidden combination

MODULATION
EQUIPMENT - EARTH

	0.51μ	0.84μ	10.6μ	13 cm
PCM/AM	NMODEF	NMODEG	NMODEI	NMODEJ
PCM/PL	NMODEF	NMODEG	NMODEI	X
PCM/FM	NMODEF	NMODEG	NMODEI	NMODEJ
PCM/PM	NMODEF	NMODEG	NMODEI	NMODEJ
PPM/AM	NMODEF	NMODEH	NMODEI	X

X - Forbidden combination

DEMODULATION
EQUIPMENT - EARTH

	Optical Direct Detection			Optical Heterodyne Detection			Optical Homodyne Detection			Radio Direct Detection 13 cm	Radio Homodyne Detection 13 cm
	0 51μ	0 84μ	10 6μ	0 51μ	0 84μ	10 6μ	0 51μ	0.84μ	10 6μ		
PCM/AM	NDMODA	NDMODA	NDMODA	X	X	X	X	X	X	X	NDMODE
PCM/PL	NDMODA	NDMODA	NDMODA	X	X	X	X	X	X	X	X
PCM/FM	X	X	X	NDMODB	NDMODB	NDMODB	X	X	X	X	NDMODE
PCM/PM	X	X	X	X	X	X	NDMODC	NDMODC	NDMODC	X	NDMODE
PPM/AM	NDMODA	NDMODA	NDMODA	X	X	X	X	X	X	X	X

X - Forbidden combination

DEMODULATION
EQUIPMENT - SPACE

	Optical Direct Detection			Optical Heterodyne Detection			Optical Homodyne Detection			Radio Direct Detection 13 cm	Radio Homodyne Detection 13 cm
	0 51μ	0 84μ	10 6μ	0 51μ	0.84μ	10.6μ	0 51μ	0 84μ	10 6μ		
PCM/AM	NDMODF	NDMODF	NDMODF	X	X	X	X	X	X	NDMODI	NDMODJ
PCM/PL	NDMODF	NDMODF	NDMODF	X	X	X	X	X	X	X	X
PCM/FM	X	X	X	NDMODG	NDMODG	NDMODG	X	X	X	NDMODI	NDMODJ
PCM/PM	X	X	X	X	X	X	NDMODH	NDMODH	NDMODH	NDMODI	NDMODJ
PPM/AM	NDMODF	NDMODF	NDMODF	X	X	X	X	X	X	X	X

X - Forbidden combination

TRANSMITTER SYSTEM
POWER SUPPLY

Spacecraft Transmitter						Earth Transmitter
RTG	Reactor	Solar Cell Mars	Solar Cell Satellite	Solar Cell Venus	Solar Cell Mercury	Generator
NXPWSA	NXPWSB	NXPWSC	NXPWSE	NXPWSF	NXPWSG	NXPWSD

RECEIVER SYSTEM
POWER SUPPLY

Spacecraft Receiver						Earth Transmitter
RTG	Reactor	Solar Cell Mars	Solar Cell Satellite	Solar Cell Venus	Solar Cell Mercury	Generator
NRPWSA	NRPWSB	NRPWSC	NRPWSE	NRPWSF	NRPWSG	NRPWSD

TRANSMITTER

	0.51 μ	0.84 μ	10.6 μ	13 cm
Spacecraft Transmitter	NXMTRA	X	NXMTRE	NXMTRG
Earth Transmitter	NXMTRB	X	NXMTRF	NXMTRH

4.6.2 System Physical Data Selection Logic

R, transmission range

RANMAR	1.0×10^{13}	cm
RANJUP	7.5×10^{13}	cm
RANSAT	3.6×10^{9}	cm

λ, transmission wavelength

LAM051	0.51×10^{-4}	cm
LAM084	0.84×10^{-4}	cm
LAM106	10.6×10^{-4}	cm
LAM13C	13	cm

S/N, signal-to-noise power ratio

	OPTDIR	OPTHET	OPTHOM	RADHET	RADHOM
PCM/AM	26	30	15	20	15
PCM/PL	12	X	X	X	X
PCM/FM	X	15	X	19	15
PCM/PM	X	X	7	X	8
PCM/AM	19	X	X	25	X

X - Forbidden Combination

C/N, carrier-to-background radiation power ratio

	OPTDIR
PCM/IM	6
PCM/PL	3
PPM/IM	1

$(u_s, \tau)_{REQ}$, required signal photoelectron count per time period τ

	OPTDIR
PCM/IM	30
PCM/PL	15
PPM/IM	20

τ_t, transmitter system transmissivity

	LAM051	LAM084	LAM106	LAM13C
PCM/AM	.8	.8	.8	.75
PCM/IM	.8	.8	.8	.75
PCM/PL	.8	.8	.8	.75
PCM/FM	.8	.8	.8	.75
PCM/PM	.8	.8	.8	.75
PPM/IM	.8	.8	.8	.75

τ_r, receiver system transmissivity

	LAM051	LAM084	LAM106	LAM13C
OPTDIR	.7	.7	.7	X
OPTHET or OPTHOM	.6	.6	.6	X
RADHET or RADDIR	X	X	X	.35

X — Forbidden Combination

τ_a, atmospheric transmissivity

	LAM051	LAM084	LAM106	LAM13C
SPXMTR and SPRCVR	.8	.8	.8	.95
SPXMTR and EARCVR or EAXMTR and SPRCVR	.8	.8	.8	.95
EAXMTR and EARCVR	.8	.8	.8	.95

ρ_T, transmitter antenna aperture efficiency

LAM051	0.98
LAM084	0.98
LAM106	0.98
LAM13C	0.60

ρ_R, receiver antenna aperture efficiency

LAM051	0.98
LAM084	0.98
LAM106	0.98
LAM13C	0.80

T_E, receiver equivalent temperature

	LAM13C	LAM084 or LAM106
BKGALT	27	X
OPTDIR	X	300

η, detector quantum efficiency

LAM051	.2
LAM084	.5
LAM106	.5

X — Forbidden Combination

R_L, receiver output load resistance

$$R_L = 100 \text{ ohms}$$

λ_i, optical filter bandwidth

$$\lambda_i = 10^{-3} \text{ microns}$$

Q_B, background radiation photon spectral radiance

	LAM051
BKMARS	X
BKJUPT	X
BKMOON	X
BKERTH	X
BKDSKY	$.2 \times 10^{-17}$
BKNSKY	$.75 \times 10^{9}$
BKGALT	0.

d_{TB}, transmitter antenna diameter stop

	LAM051	LAM084	LAM106	LAM13C
SPXMTR	10	16	100	100
EAXMTR	10	16	210	1000

G_{TB}, transmitter antenna gain stop

	LAM13C
SPXMTR	348
EAXMTR	34,800

X — Forbidden Combination

d_{RB}, receiver antenna diameter stop

	LAM051	LAM084	LAM106	LAM13C
SPRCVR and OPTDIR	100	100	100	X
SPRCVR and either OPTHET or OPTHOM	10	16	100	X
SPRCVR and either RADDIR or RADHOM	X	X	X	1000
EARCVR and OPTDIR	1000	1000	1000	1000
EARCVR and either OPTHET or OPTHOM	10	16	100	X
EARCVR and either RADDIR or RADHOM	X	X	X	6400

G_{RB}, receiver antenna gain stop

	LAM13C
SPRCVR	46,500
EARCVR	1,900,000

P_{TB}, transmitter power stop

	LAM051	LAM084	LAM106	LAM13C
SPXMTR	50	5	500	1,000
EAXMTR	100	25	1000	10,000

θ_{RB}, receiver field of view stop

	LAM051	LAM084	LAM106	LAM13C
SPRCVR	10^{-5}	10^{-5}	10^{-5}	10^{-4}
EARCVR	10^{-5}	10^{-5}	10^{-5}	10^{-4}

X — Forbidden Combination

4.7 COPTRAN Coding Sheets and Data Forms

The following pages contain the blank sheets and forms which may be used in the preparation of COPTRAN programs. The sheets are: the COPTRAN Coding Sheet A, the COPTRAN Coding Sheet B, the COPTRAN Coding Sheet C, the System Burdens Data Sheet, the System Physical Data Sheet, and the System Parameter Constraints Sheet.

The COPTRAN Coding Sheet A is generally the only coding sheet needed. Its usage is described in Section 4.3.1 and 4.3.3, where it is noted that the COPTRAN Instruction mnemonics and the COPTRAN Data may be tabulated on this form. COPTRAN Coding Sheets B and C, described in Section 4.3.3, are used if many of the Systems Burdens Data values and the System Physical Data values are to be changed. COPTRAN Coding Sheets B and C list all the labels and indicate where the decimal point is to be placed, saving some effort in preparation.

The Systems Burdens Data Sheet, the Systems Physical Data Sheet, and the Systems Parameter Constraints Sheets are provided to enable the user to consider more conveniently changes he may wish to make. Their use is not required in any part of the COPTRAN program.

COPTRAN CODING SHEET A

NAME ______________________ DATE __________ PROBLEM ______________________________

COPTRAN INSTRUCTIONS AND DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2																								
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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

COPTRAN CODING SHEET B

NAME ______________________ DATE __________ PROBLEM ______________________

SYSTEM BURDENS DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	K	T	H	T										.										
2	K	D	T											.										
3	C	K	T											.										
4	W	K	T											.										
5	M	T												.										
6	N	T												.										
7																								
8	K	A	T											.										
9	K	W	A	T										.										
10	K	P	Q	T										.										
11	C	A	T											.										
12	W	B	T											.										
13	Q	T												.										
14																								
15	K	F	M											.										
16	K	M												.										
17	K	P	M											.										
18	C	K	M											.										
19	W	K	M											.										
20																								
21	K	S	T											.										
22	K	W	S	T										.										
23	C	K	E											.										
24	W	K	E											.										
25																								

SYSTEM BURDENS DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	K	T	H	R										.										
2	K	D	R											.										
3	C	K	R											.										
4	W	K	R											.										
5	M	R												.										
6	N	R												.										
7																								
8	K	A	R											.										
9	K	W	A	R										.										
10	K	P	Q	R										.										
11	C	A	R											.										
12	W	B	R											.										
13	Q	R												.										
14																								
15	K	F	D											.										
16	K	D												.										
17	K	P	D											.										
18	C	K	D											.										
19	W	K	D											.										
20																								
21	K	S	R											.										
22	K	W	S	R										.										
23	C	K	F											.										
24	W	K	F											.										
25																								

COPTRAN CODING SHEET C

NAME ______________ DATE ________ PROBLEM ______________________

SYSTEM BURDENS DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	K	P	T											.										
2	K	W	T											.										
3	K	H												.										
4	K	X												.										
5	K	E												.										
6	C	K	P											.										
7	C	K	H											.										
8	W	K	P											.										
9	W	K	H											.										
10	G	T												.										
11	H	T												.										
12	J	T												.										
13																								
14	K	S	A											.										
15	K	S	B											.										
16																								
17																								
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22																								
23																								
24																								
25																								

SYSTEM PHYSICAL DATA

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	R													.										
2	L	A	M	B	D	A								.										
3	S	N												.										
4	C	N												.										
5	U	S	B	R	E	Q								.										
6	T	A	U	T										.										
7	T	A	U	R										.										
8	T	A	U	A										.										
9	T	E												.										
10	E	T	A											.										
11	R	L												.										
12	L	M	B	D	I									.										
13	Q	B												.										
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SYSTEM BURDENS DATA

TRANSMITTER LOCATION: ____________ DATE: ____________

RECEIVER LOCATION: ____________

TRANSMISSION WAVELENGTH: ____________

COMPONENT	PARAMETER	UNIT	VALUE	USE	COMPONENT	PARAMETER	UNIT	VALUE	USE
TRANSMITTER ANTENNA	$K_{\theta T}$	$/		TF	MODULATION EQUIPMENT	K_{FM}	$/BIT		TF
	K_{dT}	LB/		TW		K_M	LB/BIT		TW
	C_{KT}	$		TF		K_{PM}	WATT/LB		TWF
	W_{KT}	LB		TW		C_{KM}	$		TF
	m_T	--		TF		W_{KM}	LB		TW
	n_T	--		TW	DEMODULATION EQUIPMENT	K_{FD}	$/BIT		RF
RECEIVER ANTENNA	$K_{\theta R}$	$/		RF		K_D	LB/BIT		RW
	K_{dR}	LB/		RW		K_{PD}	WATT/LB		RWF
	C_{KR}	$		RF		C_{KD}	$		RF
	W_{KR}	LB		RW		W_{KD}	LB		RW
	m_R	--		RF	TRANSMITTER POWER SUPPLY	K_{ST}	$/WATT		TF
	n_R	--		RW		K_{WST}	LB/WATT		TW
TRANSMITTER ACQUISITION AND TRACK SYSTEM	K_{AT}	$/		TF		C_{KE}	$		TF
	K_{WAT}	LB/		TW		W_{KE}			TW
	K_{PQT}	WATT/LB		TWF	RECEIVER POWER SUPPLY	K_{SR}	$/WATT		RF
	C_{AT}	$		TF		K_{WSR}	LB/WATT		RW
	W_{BT}	LB		TW		C_{KF}	$		RF
	q_T	--		TF		W_{KE}	LB		RW
RECEIVER ACQUISITION AND TRACK SYSTEM	K_{AR}	$/		RF	TRANSMITTER	K_{PT}	$/		TF
	K_{WAR}	LB/		RW		K_{WT}	LB/		TW
	K_{PQR}	WATT/LB		RWF		K_H	$/WATT		TF
	C_{AR}	$		RF		K_X	LB/WATT		TW
	W_{BR}	LB		RW		k_e	--		TWF
	q_R	--		RF		C_{KP}	$		TF
GENERAL	K_{SA}	$/LB		TW		C_{KH}	$		TF
	K_{SB}	$/LB		RW		W_{KP}	LB		TW
						W_{KH}	LB		TW
						g_T	--		TF
						h_T	--		TW
						i_T	--		TWF

Use Code:
- TW — Data for transmitter weight optimization
- TF — Data for transmitter fabrication cost optimization
- RW — Data for receiver weight optimization
- RF — Data for receiver fabrication cost optimization
- TWF — Data for transmitter weight and fabrication cost optimization
- RWF — Data for receiver weight and fabrication cost optimization

SYSTEM PHYSICAL DATA

TRANSMITTER LOCATION: ____________________ DATE: __________

RECEIVER LOCATION: ____________________

PROGRAM SOP	PROGRAM TOP	PROGRAM HOP	PROGRAM ROP	PARAMETER	NAME	UNITS	VALUE
*	*	*	*	R	Range	cm	
*	*	*	*	λ	Transmission wavelength	cm	
	*	*	*	S/N	Signal-to-noise power ratio		
*				C/N	Signal to background radiation power ratio		
*				$(\mu_{S,\pi})_{Req.}$	Required signal photoelectron count per decision interval		
*	*	*	*	τ_t	Transmitter transmissivity		
*	*	*	*	τ_r	Receiver transmissivity		
*	*	*	*	τ_a	Atmospheric transmissivity		
*	*	*	*	ρ_t	Transmitter antenna aperture efficiency		
*	*	*	*	ρ_r	Receiver antenna aperture efficiency		
	*		*	T_E	Receiver temperature	°K	
*	*	*		η	Detector quantum efficiency		
	*			R_L	Receiver output load resistance	ohms	
*				λ_i	Optical filter bandwidth	micron	
*				Q_B	Photon spectral radiance	photons per cm^2 micron steradian	

Rule: Parameter may be set equal to zero if asterisk is absent in program column.

SYSTEM PARAMETER CONSTRAINTS

PARAMETER	UNITS	INITIAL	FIXED	STOP
Transmitter antenna diameter	cm	d_{TI}	d_{TM}	d_{TB}
Transmitter antenna gain	—	G_{TI}	G_{TM}	G_{TB}
Receiver antenna diameter	cm	d_{RI}	d_{RM}	d_{RB}
Receiver antenna gain	—	G_{RI}	G_{RM}	G_{RB}
Transmitter power	watt	P_{TI}	P_{TM}	P_{TB}
Receiver field of view	rad.	θ_{RI}	θ_{RM}	θ_{RB}

Rules:

1. If a parameter is to be fixed, set the stop and initial values ot the parameter to its fixed value
2. If a parameter is not to be fixed, set the fixed value equal to zero, and set the initial value to one half the stop value.
3. If a parameter is not to be optimized, nor fixed, its values may be set to zero.